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HAROLD L. BRODE

DNA 6320F

OPERATIONS
NOUGAT AND WHETSTONE

EVENTS

HARD HAT, DANNY BOY, MARSHMALLOW, MUDPACK, WISHBONE, GUMDROP, DILUTED WATERS, AND TINY TOT

15 February 1962 - 17 June 1965

United States Underground Nuclear Weapons Tests
Underground Nuclear Test Personnel Review

Prepared by Field Command, Defense Nuclear Agency

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Defense Nuclear Agency (DNA)	WHETSTONE	MUDPACK
Nevada Test Site (NTS)	DANNY BOY	GUMDROP
Underground Test (UGT)	HARD HAT	NOUGAT

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is a personnel oriented history of DOD participation in underground nuclear weapons testing during Operations NOUGAT and WHETSTONE, test events HARD HAT, DANNY BOY, MARSHMALLOW, MUDPACK, WISHBONE, GUMDROP, DILUTED WATERS, and TINY TOT. It is the first in a series of historical reports which will include all DOD underground nuclear weapons tests and DOE underground nuclear weapons tests with significant DOD participation from 1962 forward. In addition to these volumes presenting a history of the underground nuclear test

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20. ABSTRACT (Continued)

program, a later restricted volume will identify all DOD participants, (military, civilian, and their contractors) and will list their dosimetry data.

SUMMARY

Eight Department of Defense (DOD)-sponsored underground test events were conducted to study weapons effects from 15 February 1962 to 17 June 1965. Four were shaft-type, three were tunnel-type, and one was a crater-type nuclear test. The following table summarizes data on these events:

OPERATION	NOUGAT			WHETSTONE				
TEST EVENT	HARD HAT	DANNY BOY	MARSHMALLOW	MUDPACK	WISHBONE	GUMDROP	DILUTED WATERS	TINY TOT
DATE	15 FEB 62	5 MAR 62	28 JUN 62	16 DEC 64	18 FEB 65	21 APR 65	16 JUN 65	17 JUN 65
LOCAL TIME (hours)	1000 PST	1015 PST	1000 PDT	1210 PST	0819 PST	1400 PST	0930 PDT	1000 PDT
NTS LOCATION	AREA 15	AREA 18	AREA 16	AREA 10	AREA 5	AREA 16	AREA 5	AREA 15
TYPE	SHAFT	CRATER	TUNNEL	SHAFT	SHAFT	TUNNEL	SHAFT	TUNNEL
DEPTH (feet)	943	110	1000	500	600	834	640	364
YIELD (kilotons)	5.7	0.43	LOW*	2.7	LOW*	LOW*	LOW*	LOW*

*LOW INDICATES LESS THAN 20 KILOTONS

Releases of radioactivity to the atmosphere were detected both onsite and offsite after DANNY BOY, the crater-type event, and after DILUTED WATERS, a shaft-type event. Releases of radioactivity were detected only within the confines of the Nevada Test Site (NTS) after the HARD HAT, MARSHMALLOW, WISHBONE, and TINY TOT events. No release of radioactivity was detected onsite or offsite after the MUDPACK and GUMDROP test events.

As recorded on Area Access Registers, 12,152 individual entries to radiation exclusion areas were made after the above DOD test events. Of this number, 1,031 were by DOD-affiliated personnel (including military personnel, DOD civil servants, and DOD contractor personnel). The remainder were United States Atomic Energy Commission (AEC), other government agency, and contractor personnel.

The average gamma radiation exposure per entry for all personnel was 22 mR. The average gamma radiation exposure per entry for DOD-affiliated personnel was 32 mR. The maximum exposure of a non-DOD individual during an entry was 1295 mR. The maximum exposure of a DOD-affiliated individual was 1780 mR. This exposure occurred on 5 March 1962 during reentry and recovery operations after the DANNY BOY event.

Exposures of Indian Springs Air Force Base (ISAFB) personnel providing air support were not recorded on Area Access Registers, but were recorded on separate exposure reports, and their exposures are discussed separately. Considering support of DOD underground test events only, most of the exposures of Air Force personnel staging from ISAFB occurred in support of the DANNY BOY event. The maximum exposure for helicopter pilots supporting this event was 1700 mR, and the maximum exposure for sampling aircraft pilots during DANNY BOY was 295 mR.

PREFACE

The United States Government conducted 194 nuclear device tests from 1945 through 1958 during atmospheric test series at sites in the United States and in the Atlantic and Pacific oceans. The United States Army Manhattan Engineer District implemented the testing program in 1945, and its successor agency, the AEC, administered the program from 1947 until testing was suspended by the United States on 1 November 1958.

Of the 194 nuclear device tests conducted, 161 were for weapons development or effects purposes, and 33 were safety experiments. An additional 22 nuclear experiments were conducted from December 1954 to February 1956 in Nevada. These experiments were physics studies using small quantities of fissionable material and conventional explosives.

President Eisenhower had proposed that test ban negotiations begin on 31 October 1958, and had pledged a one-year moratorium on United States testing to commence after the negotiations began. The Conference on Discontinuance of Nuclear Weapons Tests began at Geneva on 31 October 1958; the U.S. moratorium began on 1 November, and the AEC detected the final Soviet nuclear test of their fall series on 3 November 1958. Negotiations continued until May 1960 without final agreement. No nuclear tests were conducted by either nation until 1 September 1961, when the Soviet Union resumed nuclear testing in the atmosphere. The United States began a series of underground tests in Nevada on 15 September 1961, and U.S. atmospheric tests were resumed on 25 April 1962 in the Pacific.

The United States conducted several atmospheric tests in

Nevada during July 1962, and the last United States atmospheric nuclear test was in the Pacific on 4 November 1962. The Limited Test Ban Treaty, which prohibited tests in the atmosphere, in outer space, and underwater was signed in Moscow on 5 August 1963. From resumption of United States atmospheric testing on 25 April 1962 until the last atmospheric test on 4 November 1962, 40 weapons development and weapons effects tests were conducted as part of the Pacific and Nevada atmospheric test operations. The underground tests, resumed on 15 September 1961, have continued on a year-round basis through the present time.

In 1977, 15 years after atmospheric testing stopped, the Center for Disease Control (CDC)* noted a possible leukemia cluster within the group of soldiers who were present at the SMOKY test event, one of the Nevada tests in the 1957 PLUMBBOB test series. After that CDC report, the Veterans Administration (VA) received a number of claims for medical benefits filed by former military personnel who believed their health may have been affected by their participation in the nuclear weapons testing program.

In late 1977, the DOD began a study to provide data for both the CDC and the VA on radiation exposures of DOD military and civilian participants in atmospheric testing. That study has progressed to the point where a number of volumes describing DOD participation in atmospheric tests have been published by the Defense Nuclear Agency (DNA) as the executive agency for the DOD.

On 20 June 1979, the United States Senate Committee on Veterans' Affairs began hearings on Veterans' Claims for Dis-

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*The Center for Disease Control was part of the U.S. Department of Health, Education, and Welfare (now the U.S. Department of Health and Human Services).

abilities from Nuclear Weapons Testing. In addition to requesting and receiving information on DOD personnel participation and radiation exposures during atmospheric testing, the Chairman of the Senate Committee expressed concern regarding exposures of DOD participants in DOD-sponsored and Department of Energy (DOE)* underground test events.

The Chairman requested and received information in an exchange of letters through 15 October 1979 regarding research on underground testing radiation exposures. In early 1980, the DNA initiated a program to acquire and consolidate underground testing radiation exposure data in a set of published volumes similar to the program underway on atmospheric testing data. This volume is the first of several volumes regarding the participation and radiation exposures of DOD military and civilian personnel in underground nuclear test events.

SERIES OF VOLUMES

Each volume of this series will discuss DOD-sponsored underground test events, in chronological order, after presenting introductory and general information. The volumes will cover all underground test events identified as DOD-sponsored in Announced United States Nuclear Tests, published each year by the DOE Nevada Operations Office, Office of Public Affairs, except events conducted as nuclear test detection experiments where reentries and, subsequently, exposure of participants to radiation did not occur.

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*The U.S. Department of Energy succeeded the U.S. Energy Research and Development Administration (ERDA) in October 1977. ERDA had succeeded the U.S. Atomic Energy Commission on 19 January 1975.

An additional volume will discuss general participation of DOD personnel in DOE-sponsored underground test events, with specific information on those events which released radioactive effluent to the atmosphere and where exposures of DOD personnel were involved.

A separate volume will be a census of DOD personnel and their radiation exposure data. Distribution of this volume will necessarily be limited by provisions of the Privacy Act.

METHODS AND SOURCES USED TO PREPARE THE VOLUMES

Information for these volumes was obtained from several locations. Security-classified documents were researched at Headquarters, DNA, Washington, DC. Additional documents were researched at Field Command, DNA, the Air Force Weapons Laboratory Technical Library, and Sandia National Laboratories (SNL) in Albuquerque, New Mexico. Most of the radiation measurement data were obtained at the DOE, Nevada Operations Office (DOE/NV), and its support contractor, the Reynolds Electrical & Engineering Company, Inc. (REECo), in Las Vegas, Nevada.

Unclassified records were used to document underground testing activities when possible, but, when necessary, unclassified information was extracted from security-classified documents. Both unclassified and classified documents are cited in the List of References at the end of each volume. Locations of the reference documents also are shown. Copies of most of the unclassified references have been entered in the records of the Coordination and Information Center (CIC), a DOE facility located in Las Vegas, Nevada.

Radiation measurements, exposure data, event data, and offsite reports generally are maintained at REECo facilities adjacent to the CIC as hard copy or microfilm, or as original hard copy at the Federal Archives and Records Center, Laguna Niguel, California. A master file of all available personnel exposure data for nuclear testing programs on the continent and in the Pacific from 1945 to the present also is maintained by REECo for DOD and DOE.

ORGANIZATION OF THIS VOLUME

A Summary of this test event volume appears before this Preface and includes general objectives of the test events, characteristics of each test event, and data regarding DOD participants and their radiation exposures.

An Introduction following this Preface discusses reasons for conducting nuclear test events underground, the testing organization, the NTS, and locations of NTS underground testing areas.

A chapter entitled underground testing procedures explains the basic mechanics of underground testing, purposes of effects experiments, containment features and early containment problems, tunnel and shaft area access requirements, industrial safety and radiological safety procedures, telemetered radiation exposure rate measurements, and air support for underground tests.

A chapter on each test event covered by the volume follows in chronological order. Each test event chapter contains an event summary, a discussion of preparations and event operations, an explanation of safety procedures implemented, and listings of monitoring, sampling, and exposure results.

Following the event chapters are a Reference List and appendices to the text including a Glossary of Terms and a list of Abbreviations and Acronyms.

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CHAPTER 1

INTRODUCTION

The first United States nuclear detonation designed to be fully contained underground was the RAINIER tunnel event conducted in Nevada on 19 September 1957. This was a weapons development experiment with a relatively low yield of 1.7 kilotons (kt). The second tunnel event was a safety experiment on 22 February 1958 also conducted in Nevada. This experiment, the VENUS event, resulted in a yield less than one ton. These two tests were the beginning of a United States underground program that is currently the only method of testing permitted by treaty.

1.1 HISTORICAL BACKGROUND

While technical conferences between the United States and the Soviet Union on banning nuclear detonation tests continued, and concern regarding further increases in worldwide fallout mounted, a number of nuclear tests were conducted underground during 1958 in Nevada. Prior to the United States testing moratorium, six safety experiments in shafts, five safety experiments in tunnels, and four weapons development tests in tunnels were conducted.

However, radioactive products from several of these tests were not completely contained underground. Containment of nuclear detonations was a new engineering challenge. Fully understanding and solving containment problems would require years of underground testing experience.

When the United States resumed testing 15 September 1961, 32 of the first 33 test events were underground and the other was a cratering experiment with the device emplaced 110 feet below the surface. The DOMINIC I test series in the Pacific and the DOMINIC II test series in Nevada during 1962 were the last atmospheric nuclear detonation tests by the United States.

The commitment of the United States to reduce levels of worldwide fallout by refraining from conducting nuclear tests in the atmosphere, in outer space, and underwater was finalized when the Limited Test Ban Treaty with the Soviet Union was signed on 5 August 1963.

1.2 UNDERGROUND TESTING OBJECTIVES

The majority of United States underground tests have been for weapons development purposes. New designs were tested to improve efficiency and deliverability characteristics of nuclear explosive devices before they entered the military stockpile as components of nuclear weapons.

Safety experiments with nuclear devices were conducted in addition to weapons development tests. These experiments tested nuclear devices by simulating detonation of the conventional high explosives in a manner which might occur in an accident during transportation or storage of weapons.

Weapons effects tests utilized device types equivalent to weapons, or actually to be used in weapons, to determine the effects of weapon detonations on structures, materials, and equipment. The devices generally were provided by one of the weapons development laboratories. However, the DOD sponsored weapons effects tests, and such tests usually involved greater numbers of participants and were more complex than the other categories of tests previously mentioned.

Effects of shock waves on rock formations, buildings, other structures, materials, and equipment have been tested. Effects of other detonation characteristics such as heat and radiation have been studied in the same manner. The most complex weapons effects tests have been those simulating high altitude detonations by using very large evacuated pipes hundreds of feet in length containing experiments.

1.3 TEST EVENTS IN THIS VOLUME

Weapons effects tests conducted from 15 February 1962 to 17 June 1965 during Operation NOUGAT and Operation WHETSTONE are discussed in this volume. Test events and objectives are listed below.

1. HARD HAT, 15 February 1962, to test capability of underground structures to withstand strong motions generated by an underground nuclear detonation in hard rock.

2. DANNY BOY, 5 March 1962, to produce information on cratering mechanism, ground shock, earth motion, propagation of energy, and other effects related to a cratering-type nuclear detonation in basalt.

3. MARSHMALLOW, 28 June 1962, to study effects of a nuclear detonation environment on equipment and materials at a simulated high altitude.

4. MUDPACK, 16 December 1964, to obtain information concerning ground shock.

5. WISHBONE, 18 February 1965, to determine response of equipment and materials in a nuclear detonation environment.

6. GUMDROP, 21 April 1965, to investigate response of equipment and materials to a nuclear detonation environment.

7. DILUTED WATERS, 16 June 1965, to provide information on response of equipment and materials in a nuclear detonation environment.

8. TINY TOT, 17 June 1965, to obtain information on transmission of ground shock from a nuclear detonation on a rock surface within an underground cavity.

1.4 DOD TESTING ORGANIZATION AND RESPONSIBILITIES

Administering the underground nuclear testing program at NTS was a joint AEC-DOD responsibility. The parallel nature of the AEC-DOD organizational structure is shown in Figure 1.1.

1.4.1 Responsibilities of the Defense Atomic Support Agency

The Armed Forces Special Weapons Project (AFSWP) was activated on 1 January 1947 (when the Atomic Energy Commission was activated) to assume residual functions of the Manhattan Engineer District. The DOD nuclear weapons testing organization was within AFSWP until 1959 when AFSWP became the Defense Atomic Support Agency (DASA).* The responsibilities of Headquarters, DASA, in Washington, DC, included providing consolidated management and direction for the DOD nuclear weapons effects and nuclear weapons testing program. The techncial direction and coordination of DOD nuclear weapons testing activities was delegated to Field Command, DASA (FCDASA), headquartered in Albuquerque, New Mexico.

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*DASA became the Defense Nuclear Agency (DNA) on 3 November 1971.

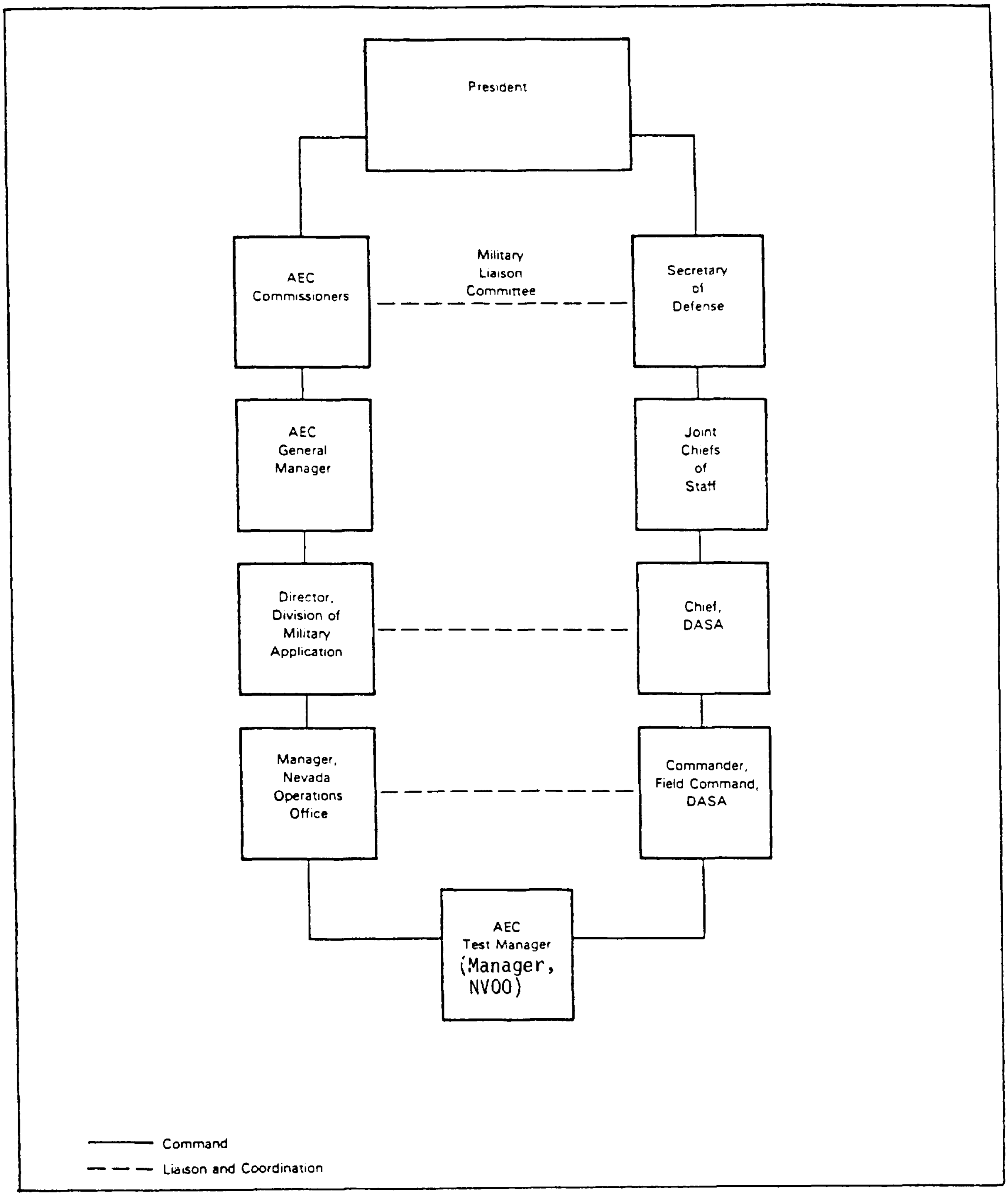

Figure 1.1 Federal Government Structure for Continental Nuclear Tests (During 1962)

The responsibilities of FCDASA in 1962 regarding DOD nuclear weapons testing activities were:

1. exercising technical direction of nuclear weapons effects tests of primary concern to the Armed Forces and the weapons effects phases of developmental or other tests of nuclear weapons involving detonations within the continental United States and overseas;

2. coordinating and supporting all DOD activities and assisting in the support of the AEC in the conduct of joint tests involving nuclear detonations within the continental United States;

3. completing detailed plans, preparing for and conducting the technical programs, and assisting in the preparation of technical and operational reports on tests; and

4. coordinating military operational training, troop participation, the troop observer program, and the DOD aspects of official visitor and public information programs. (Underground testing did not include troop participation and troop observers. The official visitor and public information programs were integrated with the AEC organization during joint AEC-DOD continental tests).

These missions were accomplished for DOD underground nuclear tests through the Field Command Weapons Effects and Tests Group (FCWT) and its Continental Test Organization (CTO).

The FCWT testing organization included Task Unit 8.1.3 for Pacific operations; administrative operations at Sandia Base in Albuquerque, New Mexico; and operations at the Nevada Test Site. The CTO conducted DOD underground nuclear tests in conjunction with the AEC weapons development laboratory test groups.

1.4.2 Nevada Test Site Organization

In the joint AEC-DOD testing program, FCWT and CTO were a part of the Nevada Test Site Organization (NTSO) as shown in Figure 1.2. The Military Deputy to the Test Manager was the Deputy Chief of Staff, FCWT, and FCWT personnel provided DOD coordination and support.

CTO was a Test Group along with Los Alamos Scientific Laboratory (LASL), Lawrence Radiation Laboratory (LRL), Sandia Corporation (SC), and Civil Effects Test Organization (CETO). The CTO is shown in Figure 1.3. In addition to his position as Military Deputy to the Test Manager, the Deputy Chief of Staff, FCWT, also was the CTO Test Group Director.

The Programs Division was responsible for scientific programs conducted by the CTO. Engineering and construction of test facilities and experiment installations were administered by the Support Division. The Operations Division was responsible for preparing technical and operations plans, and coordinating air support operations with the Air Force Special Weapons Center (AFSWC), the Tactical Air Command, and the AEC.

1.4.3 Air Force Special Weapons Center Support

The commander of AFSWC was requested by FCDASA to provide air support to the NTSO during nuclear tests at NTS. Direct support was provided by the Nuclear Test Directorate, the Special Projects Division, and the 4900th Air Base Group of AFSWC. The 4900th Air Base Group provided C-47 aircraft for shuttle service between Kirtland AFB, New Mexico, and Indian Springs AFB (ISAFB). The 4900th also provided U-3A aircraft and crews to perform low-altitude cloud tracking, and C-47 aircraft and crews for radio relay and courier missions.

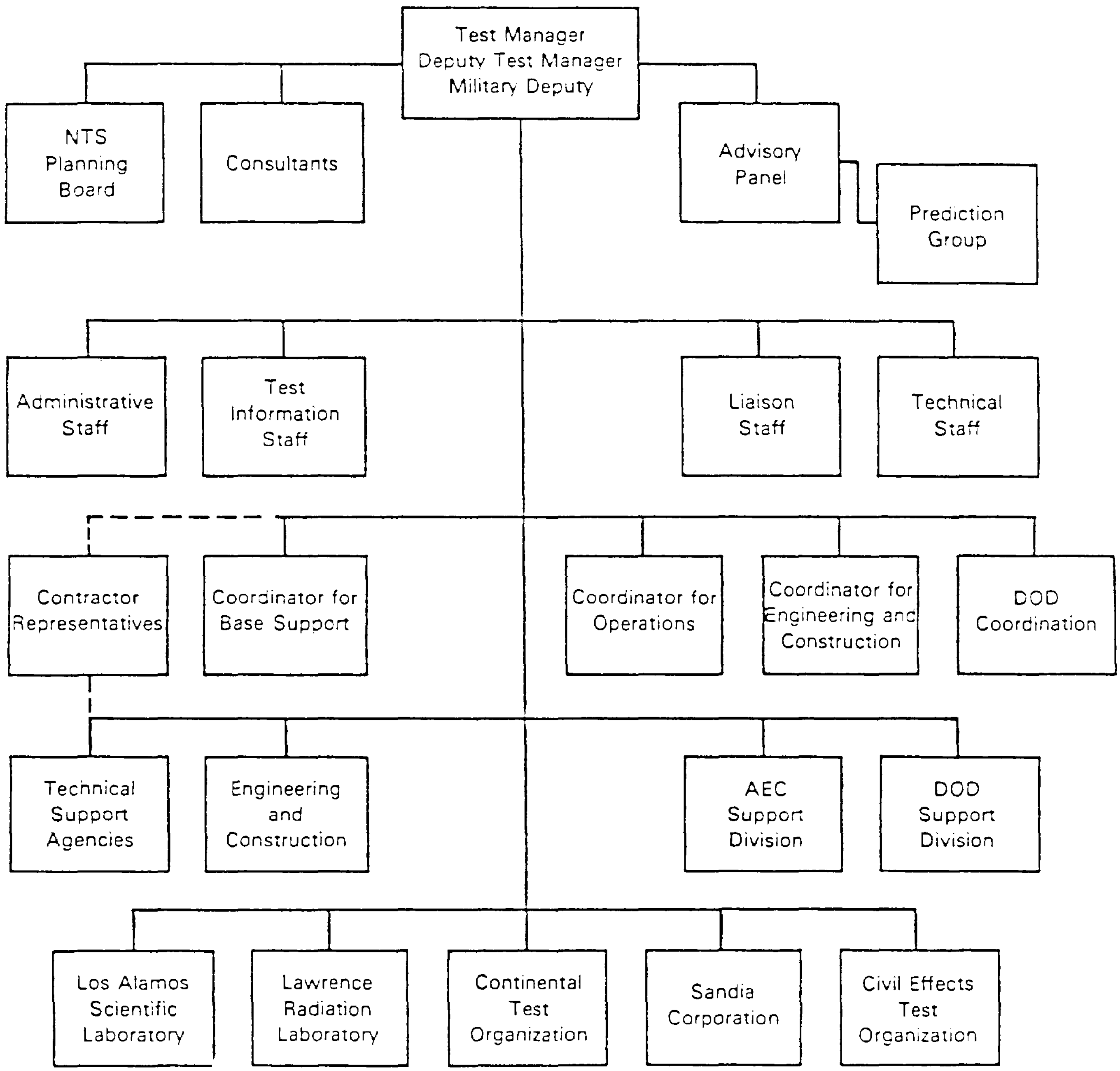

Figure 1.2 Nevada Test Site Organization (In 1962)

——— Command

– – – – Liaison and Coordination

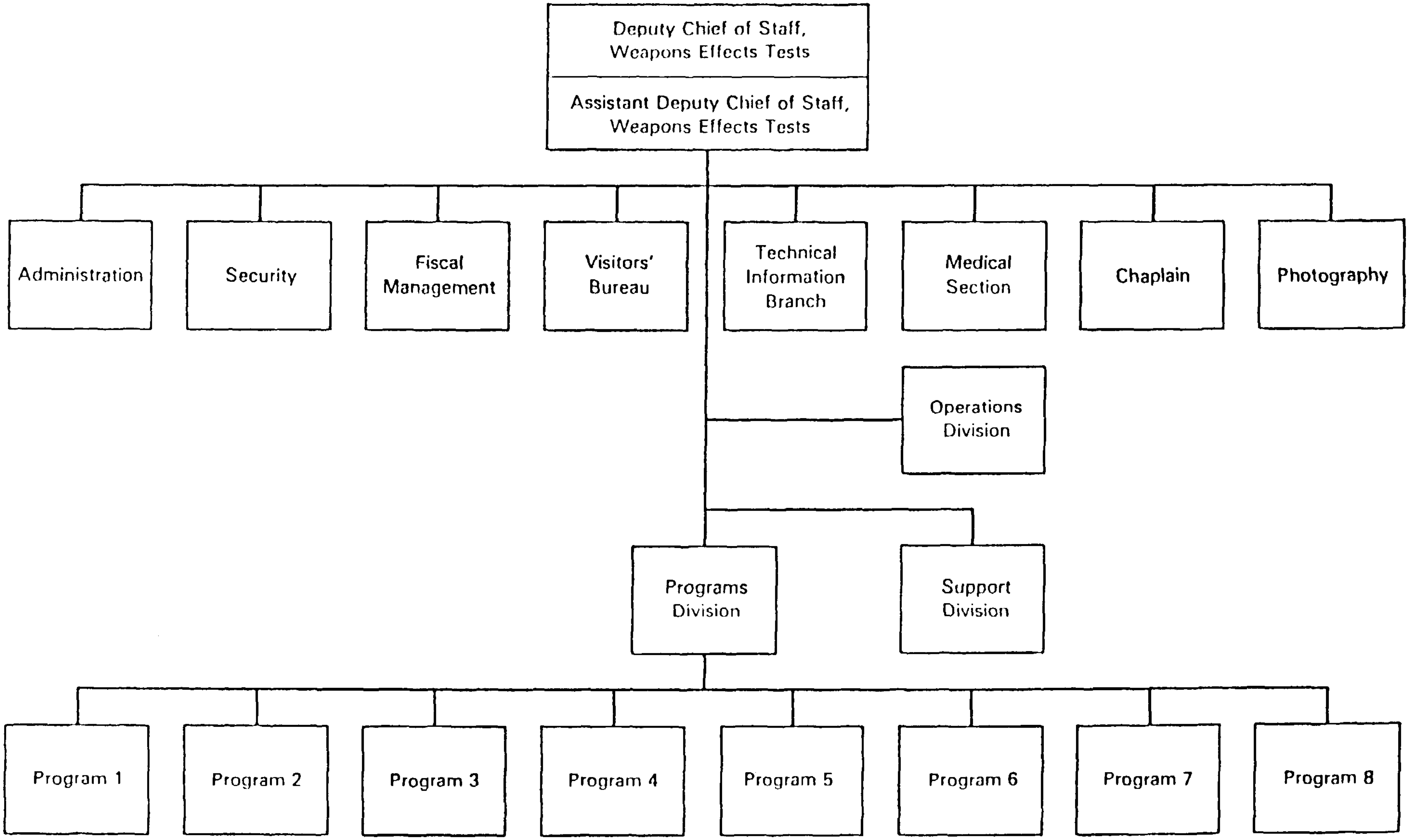

Figure 1.3 Continental Test Organization (In 1962)

Other Air Force organizations providing support to the NTSO under AFSWC control on a temporary basis were as follows:

1. Elements of the 1211th Test Squadron (Sampling), Military Air Transport Service, McClellan AFB, were detached to ISAFB. Their primary task was cloud sampling. This included maintaining the B-57 sampling aircraft, conducting cloud sampling, removing sample filters, and packaging and loading samples onto courier aircraft. Personnel from this unit also assisted NTSO radiological safety personnel in providing support at ISAFB, including decontamination of aircraft, crews, and equipment.

2. Elements of the 4520th Combat Crew Training Wing, Tactical Air Command, Nellis AFB, provided support functions, such as housing, food, and logistics, to the units operating from ISAFB and Nellis AFB. In addition, they conducted security sweep flights over NTS, and control tower operations, fire-fighting, and crash rescue services at ISAFB. They also maintained and provided equipment for the helicopter pad at the NTS Control Point and other helicopter pads at Forward Control Points.

3. The 55th Weather Reconnaissance Squadron, Military Air Transport Service, McClellan AFB, supplied one aircraft and a crew to perform high-altitude cloud tracking.

4. The Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson AFB, provided aircraft and crews to perform technical projects.

Complete Air Force support as described in this section was available for the DOD cratering event, DANNY BOY, discussed in Chapter 4 of this report, and during the last atmospheric nuclear weapons tests at NTS in July 1962. As the DOD underground testing program continued, and the probability of venting radioactive effluent to the atmosphere decreased, less cloud sampling and tracking support was required. However, air support for security sweeps of areas surrounding test locations and for photography missions during events was a continuing requirement.

1.5 RELATIONSHIP OF THE DOD, THE AEC, AND CONTRACTOR ORGANIZATIONS

The DOD was responsible for establishing nuclear weapons criteria, developing and producing delivery vehicles, obtaining military effects data, and defending against nuclear attack.

The AEC was responsible for development, production, and supply of nuclear weapons to the Armed Forces in quantities and types specified by the Joint Chiefs of Staff (JCS). The AEC, in association with the DOD, also was responsible for providing field nuclear test facilities in the continental United States and overseas.

1.5.1 The Weapons Test Division (STWT, DASA) and the Nevada Operations Office (AEC/NVOO)

The principal points of field coordination between the AEC and the DOD were at Las Vegas and the Nevada Test Site. The STWT, DASA, represented the Director, DASA, and DOD; and the AEC/NVOO represented the AEC in the field for continental tests. Each of these organizations' primary interest was field testing of nuclear weapons. Daily close liaison was maintained between the STWT, DASA, and the AEC/NVOO during planning phases for field test programs of primary interest to the DOD.

During test operations, military and AEC personnel were combined into a single test organization. Normally, the senior member of the combined test organization was the Manager, NVOO.

His deputy was the Director, Weapons Test Division, DASA. Other personnel in this joint test organization were selected from those available on a best-qualified basis. In accomplishing this, personnel were drawn not only from STWT and NVOO but from other agencies of DASA, the Armed Forces, military laboratories, military contractors, universities, civilian laboratories, AEC laboratories, AEC contractors, other government agencies, and from other sources when special qualifications or knowledge were required.

The Nevada Test Site was an AEC installation. The Manager, NVOO, was responsible for operation of this installation. The DOD and AEC laboratories were the principal users of the Test Site. The Weapons Test Division, DASA, was the single military agency and point of contact for the Manager, NVOO, for all matters pertaining to DOD field test programs, and supported all DOD agencies operating at the Test Site.

To accomplish these two major responsibilities, STWT, DASA, had an office, the Nevada Operations Branch (NOB), in the AEC Building in Las Vegas. The Nevada Operations Branch, STWT, DASA, maintained daily liaison with NVOO at the top management level on all DOD matters pertaining to field operations and had under its control the Nevada Test Site Section to support DOD agencies at the site. For DOD agencies, the office also provided a point of contact to assist in matters of interest with NVOO and to provide transportation and quarters in Las Vegas. All DOD personnel and DOD contractor personnel connected with nuclear field tests were under administrative control of this office while in Las Vegas and at the Nevada Test Site.

The Nevada Test Site Section, with 47 permanently assigned personnel in 1962, coordinated DOD activities and supported DOD agencies operating at the Test Site. This section was located at the DOD Compound in Mercury (see section 1.5) and provided office and laboratory space, transportation, test equipment, and logistical and administrative support.

1.5.2 Test Organizations

Before 1957, the Test Director for each series had been a representative of the Los Alamos Scientific Laboratory. For the 1957 PLUMBBOB series, a staff member of the Lawrence Radiation Laboratory was appointed to the position, reflecting the growing participation by the Lawrence Radiation Laboratory in test operations. After 1961, the Test Director for events of primary interest to the DOD was an officer from one of the Services. The Test Director was responsible for overall coordination and scientific support for the entire scientific test program; for planning and coordination; and for positioning, arming, and detonating test devices. Generally, the AEC weapons laboratories provided the nuclear devices for DOD test events.

Other officials of the joint test organization were responsible for various functions, such as logistical support, weather prediction, fallout prediction, blast prediction, air support, public information, radiological safety, industrial safety, and fire protection.

LOS ALAMOS SCIENTIFIC LABORATORY was established early in 1943 at Los Alamos, New Mexico, for the specific purpose of developing an atomic bomb. Los Alamos scientists supervised the test detonation of the world's first atomic weapon in July 1945 at the TRINITY site in New Mexico. The Laboratory's continuing assignment was to conceive, design, test, and develop nuclear components of atomic weapons. The Laboratory was operated by the University of California.

LAWRENCE RADIATION LABORATORY was established as a second AEC weapons laboratory at Livermore, California, in 1952. The

Laboratory's responsibilities were essentially parallel to those of the Los Alamos Scientific Laboratory. Devices developed by LRL were first tested in Nevada in 1953, and they have been tested in each continental and Pacific series since. The contract under which the LRL performed work for the AEC was administered by the Commission's San Francisco Operations Office. This Laboratory also was operated by the University of California.

SANDIA LABORATORY (later Sandia Laboratories) at Sandia Base, Albuquerque, New Mexico, was the AEC's other weapons laboratory. It was established in 1946 as a branch of the Los Alamos Scientific Laboratory, but in 1949 it assumed its identity as a full-fledged weapons research institution operated by the Sandia Corporation, a non-profit subsidiary of Western Electric. Sandia Laboratory's role was to conceive, design, test, and develop the non-nuclear phases of atomic weapons and to do other work in related fields. In 1956, a Livermore Branch of the Laboratory was established to provide closer support to developmental work of the LRL. Sandia Corporation also operated ballistic test facilities for the AEC at the Tonopah Ballistics Range near Tonopah, Nevada.

DEFENSE ATOMIC SUPPORT AGENCY was located in Washington, D.C. and was composed of personnel of the Armed Services and civilian DOD employees. It was activated on 1 January 1947 to assume certain residual functions of the Manhattan Engineer District and to assure continuity of technical military interest in nuclear weapons. The broad mission of DASA was planning specified technical services to the Army, Navy, Air Force, and Marine Corps in the military application of nuclear energy. Among the services performed were maintaining liaison with the AEC laboratories in the development of nuclear weapons, planning and supervising the conduct of weapons effects tests and other field exercises, providing nuclear weapons training to military personnel, and storing and maintaining nuclear weapons. Early in the program for testing nuclear devices and weapons, DASA was charged with the responsibility for planning and integrating with the AEC for military participation in full scale tests. After the Nevada Test Site was activated, this planning responsibility was broadened to include conducting experimental programs of primary concern to the Armed Forces and coordinating other phases of military participation including assistance to the AEC. The Director, DASA, was responsible to the Joint Chiefs of Staff and the Secretary of Defense.

Weapons Test Division (STWT) at Sandia Base, New Mexico, carried out the weapon field testing responsibilities and seismic research responsibilities (VELA-UNIFORM) for the Director, DASA. This organization maintained close liaison with the AEC Nevada Operations Office. Personnel from the STWT became the military members of the Joint AEC-DOD test organization at the Nevada Test Site and other continental United States test areas. All participation of DOD agencies and their contractors in nuclear field tests was coordinated and supported by STWT.

Nevada Operations Branch (NOB) located in Las Vegas, Nevada, maintained daily liaison with the AEC/NVOO, and supervised the STWT Test Site Section at the Nevada Test Site. In addition to the continental test responsibilities, STWT provided key personnel for the military scientific test unit, and managed the technical and scientific programs for DOD agencies and contractors during overseas tests.

1.5.3 Support Contractors

In keeping with its policy, the Atomic Energy Commission utilized private contractors for maintenance, operation, and construction (including military and civil defense construction) at the Nevada Test Site. Personnel of the Nevada Operations Office administered all housekeeping, construction, and related services activity, but performance was by contractors. The major contractors were the following:

Reynolds Electrical & Engineering Company (REECo) was the principal AEC operational and support contractor for the NTS, performing community operations, housing, feeding, maintenance, construction, and scientific structures support services. REECo maintained offices in Las Vegas and extensive facilities at the NTS.

Edgerton, Germeshausen & Grier, Inc., (EG&G) of Boston, Massachusetts, was the principal technical contractor, providing control point functions such as timing and firing, and diagnostic functions such as scientific photography and measurement of detonation characteristics. EG&G facilities were maintained in Las Vegas and at the NTS.

Holmes & Narver, Inc., (H&N) performed architect-engineer services for the NTS and was the principal support contractor for the Commission's off-continent operations. H&N had a home office in Los Angeles, and also maintained offices in Las Vegas and at the NTS.

Fenix & Scisson (F&S) of Tulsa, Oklahoma, was the consultant for NTS drilling activities.

Numerous other contractors, selected on the basis of lump-sum competitive bids, performed various construction and other support functions for the AEC and the DOD.

1.6 THE NEVADA TEST SITE

An on-continent location was selected for conducting nuclear weapons tests; construction began at the Nevada Proving Ground

(NPG) in December 1950; and testing began in January 1951. This testing area was renamed the Nevada Test Site in 1955.

The original NPG boundaries were expanded as new projects and testing areas were added. Figure 1.4 shows the present NTS location bounded on three sides by the Nellis Air Force Range. The area of NTS is about 1,350 square miles. The testing location was selected for both safety and security reasons. The arid climate, lack of industrialization, and exclusion of the public from Nellis Air Force Range combined to result in a very low population density in the area around the NTS.

The only paved roads within the NTS and Air Force Range complex were those constructed by the government for access purposes. The NTS testing areas were physically protected by surrounding rugged topography. The few mountain passes and dry washes where four-wheel-drive vehicles might enter were posted with warning signs and barricades. NTS security force personnel patrolled perimeter and barricade areas in aircraft and vehicles. Thus, unauthorized entry to NTS was difficult, and the possibility of a member of the public inadvertently entering an NTS testing area was extremely remote.

Figure 1.5 shows the NTS, its various area designations, and locations of the eight test events covered by this volume. Generally, the "U" means an underground location, the number the area, and the "a" the first test location in an area. In addition, for underground tunnels, the "a.02" indicates the second drift in a tunnel complex, as U16a.02 in Figure 1.5. A low mountain range separates the base camp, Mercury, from the location of early DOD atmospheric weapons effects tests on Frenchman Flat in Area 5. A few shaft-type underground tests also were conducted in this area. The elevation of Frenchman Dry Lake in the middle of the Flat is about 3,100 feet.

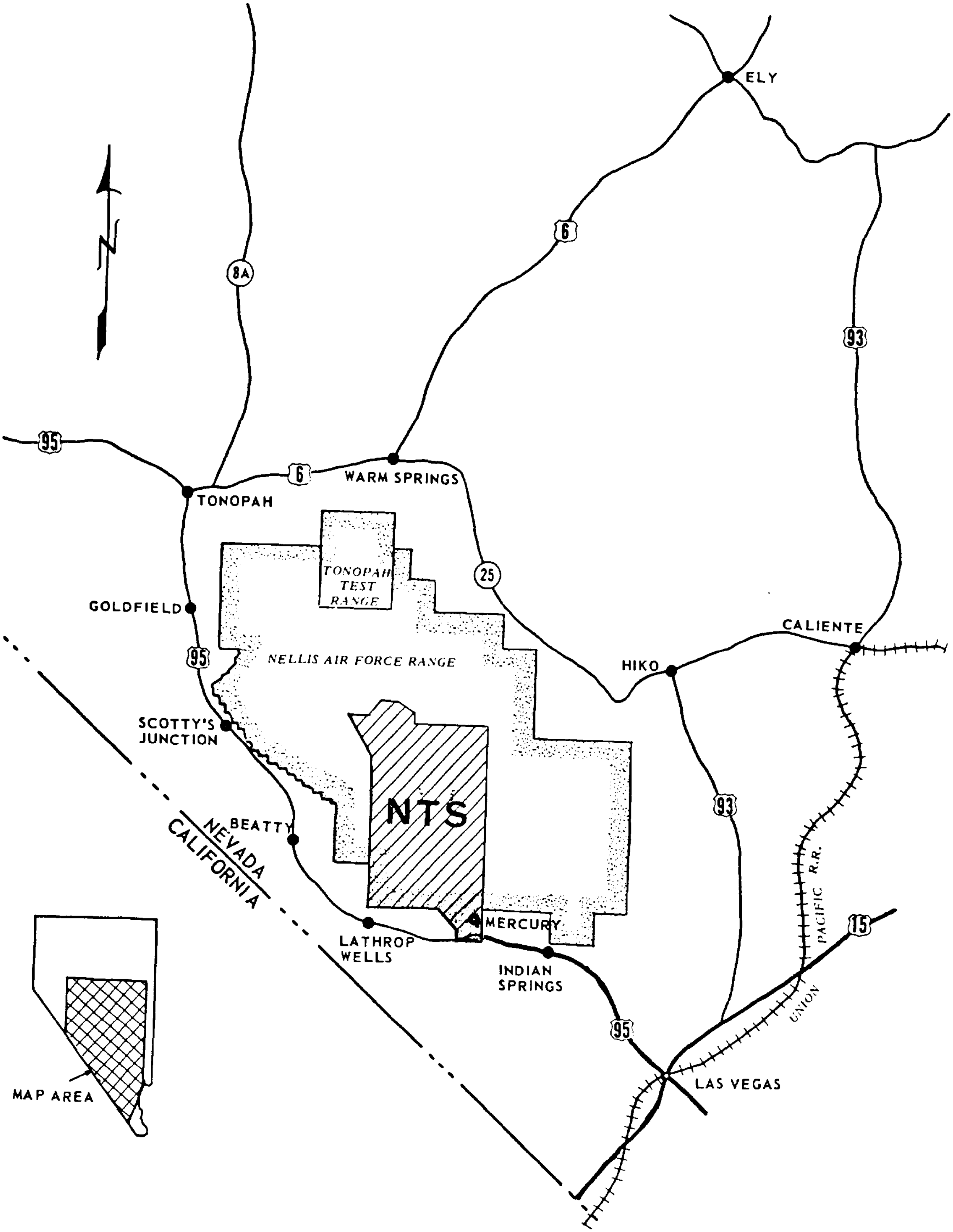

Figure 1.4 Nellis Air Force Range and NTS in Nevada

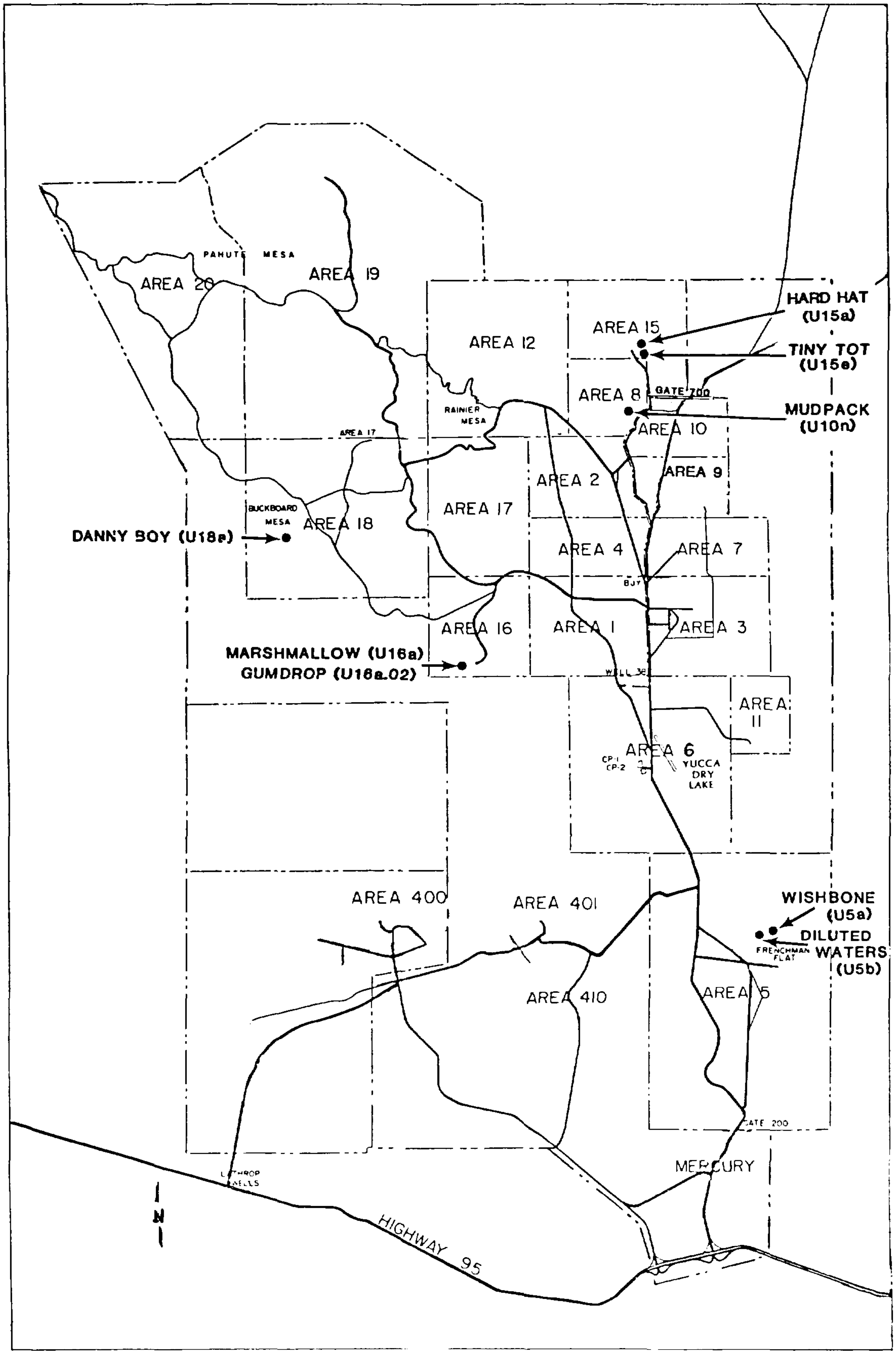

Figure 1.5 The Nevada Test Site

A mountain pass separates Frenchman Flat from Yucca Flat testing areas. The pass overlooks both Frenchman and Yucca Flats and contains the control point complex of buildings including Control Point Building 1 (CP-1) where timing and firing for most atmospheric tests was performed, and Control Point Building 2 (CP-2) where radiological safety support was based.

Yucca Flat testing areas include Areas 1, 2, 3, 4, 7, 8, 9, and 10. Underground tests have been conducted in some of these areas and generally were shaft emplacement types. The elevation of Yucca Dry Lake at the south end of Yucca Flat is about 4,300 feet. To the west of Yucca Flat, in another basin, is the Area 18 testing location. Some DOD atmospheric tests were conducted in Area 18, and one DOD cratering event, DANNY BOY, was conducted on Buckboard Mesa in this area at an elevation of about 5,500 feet. Area 16 is in the mountains west of Yucca Flat toward Area 18. The single Area 16 tunnel complex at an elevation of about 5,400 feet was a DOD underground testing location.

Rainier Mesa is in Area 12 northwest of Yucca Flat, and the top of the Mesa is at an elevation of about 7,500 feet. All tunnel-emplacement type events on NTS that were not in the Area 16 tunnel complex or the Area 15 shaft and tunnel complex were in Rainier Mesa. The major Rainier Mesa tunnel complexes were B, E, G, N, and T tunnels.

Area 15 is in the foothills at the north end of Yucca Flat. An access shaft drops 1,500 feet below the surface elevation of 5,100 feet. Two DOD events were conducted in Area 15 during the period covered by this report. The first detonation was in an emplacement shaft drilled north of an access shaft and instrumentation tunnel complex. The other detonation was at the end of a tunnel constructed from another access shaft.

CHAPTER 2

UNDERGROUND TESTING PROCEDURES

Underground tests conducted at NTS prior to 15 February 1962 primarily were for weapons development or safety experiment purposes. The experience gained contributed substantially to the DOD weapons effects underground testing program. However, these later DOD underground tests generally were of greater complexity than previous underground tests. Also, a number of technical problems remained to be solved.

Obtaining satisfactory test data was an important objective, but equally important was the objective of assuring safety of test participants and the public. This chapter discusses underground testing methods, problems encountered, and safety procedures used during DOD underground weapons effects tests conducted from 15 February 1962 to 17 June 1965.

2.1 EMPLACEMENT TYPES

The DOD conducted eight underground nuclear test events during this period. Table 2.1 lists these events and pertinent data including emplacement type. There were four shaft, one crater, and three tunnel types. Each of these is discussed in this section.

2.1.1 Shaft-Type

A shaft-type nuclear detonation is intended to be contained underground. The shaft is usually drilled, but sometimes mined, and it may be lined with a steel casing or be uncased. The nuclear device is emplaced at a depth established to contain the explosion. This depth also is selected to allow formation of a

TABLE 2.1

DOD TEST EVENTS

15 FEBRUARY 1962 - 17 JUNE 1965

OPERATION	NOUGAT			WHETSTONE				
TEST EVENT	HARD HAT	DANNY BOY	MARSHMALLOW	MUDPACK	WISHBONE	GUMDROP	DILUTED WATERS	TINY TOT
DATE	15 FEB 62	5 MAR 62	28 JUN 62	16 DEC 64	18 FEB 65	21 APR 65	16 JUN 65	17 JUN 65
LOCAL TIME (hours)	1000 PST	1015 PST	1000 PDT	1210 PST	0819 PST	1400 PST	0930 PDT	1000 PDT
NTS LOCATION	AREA 15	AREA 18	AREA 16	AREA 10	AREA 5	AREA 16	AREA 5	AREA 15
TYPE	SHAFT	CRATER	TUNNEL	SHAFT	SHAFT	TUNNEL	SHAFT	TUNNEL
DEPTH (feet)	943	110	1000	500	600	834	640	364
YIELD (kilotons)	5.7	0.43	LOW*	2.7	LOW*	LOW*	LOW*	LOW*

*LOW INDICATES LESS THAN 20 KILOTONS

subsidence crater. At detonation time, a cavity is formed by vaporized rock under pressure which holds surrounding broken rock in place until the cavity cools sufficiently to decrease pressure. As broken rock falls into the cavity formed by the detonation, the chimney of falling rock reaches the surface and a subsidence crater forms. Figure 2.1 shows a typical subsidence crater and postevent drilling operation.

2.1.2 Crater-Type

A crater-type nuclear detonation is intended to produce a crater excavated by the nuclear explosion. The nuclear device is emplaced in a shaft at a depth calculated to allow the explosion to eject broken rock from the crater. Some of the material ejected from the crater falls back, resulting in a shallower crater than the original depth of emplacement, and trapping much of the residual radioactivity underground. Figure 2.2 shows the DANNY BOY excavation crater discussed in Chapter 4.

2.1.3 Tunnel-Type

A tunnel-type nuclear detonation is intended to be completely contained. The nuclear device is emplaced in a mined opening at a depth which usually does not allow chimneying of broken rock to the surface. A tunnel emplacement may be at the end of a single horizontal tunnel into a mountain or mesa, in one tunnel of a complex of horizontal tunnels used for experiments and other nuclear detonations, in a horizontal tunnel from the bottom of a vertical shaft, or in an opening of variable size and shape mined from a tunnel or the bottom of a shaft. Figure 2.3 shows the portal of a typical DOD tunnel complex.

2.2 DIAGNOSTIC TECHNIQUES

The major advantage of underground testing was containment

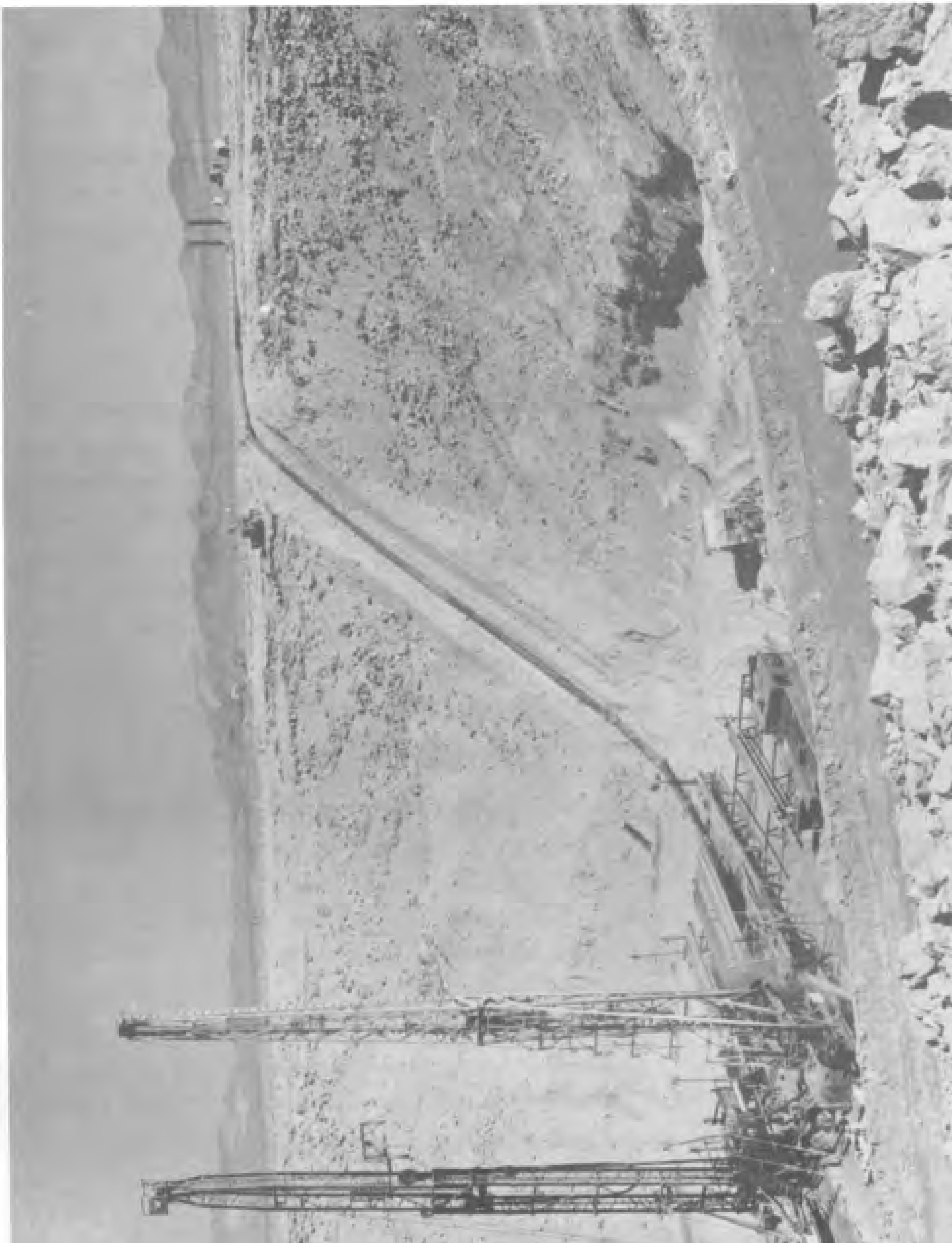

Figure 2.1 A Typical Subsidence Crater and Postevent Drilling Operation

Figure 2.2 DANNY BOY Excavation Crater

Figure 2.3 Portal of Typical DOD Tunnel Complex

of radioactive material. One of the major disadvantages was increased difficulty in determining characteristics of a detonation. Photographing a fireball growing in the atmosphere was no longer possible. Samples of a radioactive cloud for analysis no longer could be obtained by sampling aircraft. Measurements of thermal radiation, nuclear radiation, and blast were complicated by the confining underground structures. These disadvantages were overcome by developing new diagnostic techniques, some of which are discussed below.

2.2.1 Radiation Measurements

Measurements of radiations from an underground detonation were made possible by developing a system of remote detectors and cabling to send signals to recording facilities located on the surface. Detectors utilizing various physical characteristics of the radiations to be measured were installed near the nuclear device. High-specification coaxial cable and connectors carried the measurement signals to the surface where electronic equipment recorded the signals.

The detector signals were on the way to recording equipment in billionths of a second after a detonation, before detectors were destroyed. These measurement systems required the most advanced electronic technology available. Indeed, considerable research and development was necessary to acquire and refine these capabilities.

2.2.2 Radiochemical Measurements

Because clouds from atmospheric detonations no longer were available to sample, techniques were developed to obtain samples of debris from underground detonations for radiochemical analyses and subsequent yield determinations. The first systems were radiochemical sampling pipes leading directly from the device emplacements to filtering equipment on the surface. These pipes required fast-closure systems to prevent overpressure from venting radioactive effluent to the atmosphere after samples were collected.

While these systems functioned as intended for most detonations, the systems did not function properly during some tests, and radioactive effluent was released to the atmosphere. Subsequently, the use of radiochemical sampling pipes to the surface was discontinued.

The major radiochemistry sampling method which continued in use for shaft detonations was postevent core drilling. The objective of this drilling was to obtain samples of solidified radioactive debris which had collected in a molten pool at the bottom of the cavity produced by the detonation. This method required and resulted in development of precise directional drilling techniques and several advancements in the science of core drilling.

2.2.3 Line-of-Sight (LOS) Pipes

Most of the DOD shaft-type detonations included LOS pipes from the device emplacement to the surface. These pipes allowed effects experiments to be conducted as well as measurement of radiations from the detonations.

However, the LOS pipes to the surface required fast-closure systems as did the radiochemical sampling pipes, and use of LOS pipes to the surface also resulted in some releases of radioactive effluent to the atmosphere. Thus, the frequency of DOD shaft-type events, including use of these pipes to the surface, decreased, but the use of horizontal LOS pipes in underground tunnel complexes became frequent and a valuable weapons effects testing system.

2.3 EFFECTS EXPERIMENTS

Weapons effects experiments were the primary reason for conducting DOD underground nuclear detonations. The effects of blast, heat, and radiation from a nuclear detonation in the atmosphere had been studied extensively. Structures, equipment, and materials had been exposed to atmospheric detonations, and military hardware also had been exposed to underwater detonations. Underground testing provided an opportunity to study effects of ground shock and motion, and, of particular importance, the effects of a nuclear detonation environment on equipment and materials at a simulated high altitude.

The simulation of a high-altitude detonation was made possible by enlargement and improvement of the LOS pipe system discussed in section 2.2.3. Large-diameter pipes hundreds of feet long were constructed underground. The device was emplaced at the end of the pipe. An access tunnel sometimes was constructed parallel to the LOS tunnel, and short tunnels connected the two at intervals. Hatches allowed access to the LOS pipe and sealing of the pipe. Equipment and materials were installed at locations within the LOS pipe. The atmosphere in the LOS pipe was reduced in pressure by vacuum pumps, to simulate a high altitude, before the detonation. Thus, testing of weapons effects was extended from atmospheric and underwater to underground and at simulated high altitudes.

2.4 CONTAINMENT FEATURES AND PROBLEMS

Completely containing radioactive material underground while accomplishing diagnostic measurements and effects tests proved to be a major engineering challenge. Original efforts considered only detonation containment in competent rock formations. It was necessary to modify the original efforts to consider zones of weakness in rock caused by faults and containment failures caused by diagnostic and experiment structures. In addition, decreased compressibility of rock caused by high water content with subsequent greater ground motion and stress toward the surface caused containment failure. Failures also were caused by unanticipated additional overpressure of secondary gas expansion or steam pressure. The major containment features and problems that evolved are discussed below.

2.4.1 Shaft Containment

Some of the first shaft-type safety experiments were in open shafts. When nuclear yields were produced, open shafts did little to contain the radioactive debris. The first method used to contain detonations in shafts was stemming, or filling the shaft with aggregate and sand after device emplacement. Later, stemming was used that had ground-matching characteristics, such as transmission of shock waves and other properties that would not contribute to containment failure.

Keyed concrete plugs at different depths in the shaft stemming sometimes were used. The shaft diameter was enlarged at the plug construction location so the poured concrete plug would key into the ground surrounding the shaft and provide more strength against containment failure. Combinations of concrete and epoxy were used later, and epoxy has replaced concrete as a plug material for some shaft-type emplacements.

Radiochemical sampling pipes, LOS pipes, and other openings in stemming and plug containment features had to be closed rapidly after the detonation to prevent venting of radioactive effluent to the atmosphere. Fast-gate closure systems driven by high explosives or compressed air were developed to seal openings. After some of these systems did not prevent releases of effluent to the atmosphere, use of openings to the surface for diagnostic or experiment purposes was discontinued for several years until technology improved.

Scientific and other cables from the device emplacement to the surface were another source of containment problems. While cables could be imbedded in concrete and epoxy, which effectively prevented leakage along the outside of the cables, radioactive gases under high pressure traveled along the inside of cables as a conduit to the surface. This problem was solved by imbedding the inner components of cables in epoxy at convenient locations or intervals, such as at connectors, in a technique called gas blocking.

The most serious containment problems were caused by unanticipated geologic and hydrologic conditions at particular test locations. Even careful and rigorous calculations, engineering, construction, and preparations were inadequate when the presence of a geologic zone of weakness near the detonation point and toward the surface was unknown.

Another similar problem was the presence of higher water content than anticipated in rock formations surrounding or near the detonation point. This problem caused (1) greater shock transmission and ground movement by decreasing rock compressibility, (2) additional secondary gas expansion when the water turned to steam, (3) a much higher and longer-sustained pressure from the detonation point toward the surface, and (4) subsequent failure of the geologic or constructed containment mechanisms.

Recognizing and understanding geologic and hydrologic conditions at each test location was necessary before these containment problems could be solved. As additional information became available through drilling and intensive geologic studies, these problems were resolved by investigations of proposed detonation locations and application of detailed site selection criteria.

2.4.2 Tunnel Containment

As with shaft-type detonations, containment methods used for tunnel events were designed using basic characteristics of the nuclear detonation. Tunnel configurations were constructed with device emplacements strategically located to cause sealing of the access tunnel by force of the detonation. Additional containment features were used to contain radioactive debris.

A short distance from the projected self-sealing location toward the tunnel entrance (portal), one or more sandbag plugs were installed. Two plugs, each about 60 feet in length, were a typical installation. Farther toward the portal, and before entering the main tunnel in a complex with more than one test location, a keyed concrete plug with a metal blast door was constructed. The blast door was designed to contain any gases, with pressures up to 75 pounds per square inch (psi), that might penetrate the plugs.

Also as with shaft-type detonations, the unknown presence of undesirable geologic and hydrologic conditions sometimes caused venting of radioactive effluent either through the overburden (ground above the tunnel) to the surface, through fissures opened between the detonation point and the main tunnel, or through the plugs and blast door to the main tunnel vent holes and portal. More substantial containment features evolved as containment problems became better understood and tunnel events became more complex.

Generally, the sandbag plugs became solid sand backfill hundreds of feet long, and the blast door evolved into a massive overburden (equivalent) plug separating the test location tunnels from the main tunnel. The plug typically was 20 to 30 feet of keyed concrete with a large steel door containing a smaller access hatch, and was designed to withstand overpressure up to 1000 psi.

Use of the LOS pipe in tunnel events necessitated development of additional containment and closure systems. The LOS pipe tunnel and its access tunnels were separated from the main tunnel by the overburden plug. Additional containment and closure systems were for protection of the LOS pipe and its experiments as well as preventing release of effluent to the surface.

Generally, the tunnel volume outside of the pipe was filled with stemming, grouting, or by other means to facilitate containment, while the inside of the pipe and its experiments were protected by fast-closure systems. Various systems were in use including compressed air or explosive-driven gates and doors which closed off the LOS pipe from the detonation within a small fraction of a second after detonation time.

The same gas blocking techniques as used in shaft events were used to prevent leakage of radioactive gases along or through cables from the diagnostic and experiment locations to the surface. Additionally, a gas seal door usually was installed in the main drift nearer the portal than the overburden plug. Utility pipes, such as for compressed air, that passed through stemming and plugs also were sealed by closure systems.

Containment systems evolved to the point that release of detectable radioactivity to the atmosphere seldom occurred.

2.5 TUNNEL AND DRILLING AREA ACCESS REQUIREMENTS

Access to underground workings and drilling sites was controlled for a number of reasons. During construction, safety of both workers and visitors in these locations could have been jeopardized by carelessness or seemingly harmless activities of untrained and uncontrolled visitors. When security-classified material was in these locations, only personnel with appropriate security clearances were permitted access. The presence, or anticipated presence, of radioactive material in these locations required access control for radiological safety purposes. Access requirements established for the above purposes are discussed below.

2.5.1 Tunnel Access Control

During construction and preparations for a DOD event in a tunnel or other underground working, the tunnel superintendent was responsible to the project manager for safety of personnel underground. All persons going underground, or the supervisors of working groups, were required to enter appropriate information in the tunnel log book. Visitors and other personnel not assigned to work in the tunnel obtained permission for entry from the superintendent, or his representative, and were apprised of tunnel conditions and safety regulations. In the event of an accident or other emergency condition underground, the log book provided information on numbers of personnel and their locations underground.

When classified material was in the tunnel, and during initial reentry after an event, the DOD Test Group Director, or his representative, was responsible for entry and safety of personnel underground. Security personnel checked for proper security and entry clearances, and maintained records of all personnel entering the tunnel.

Control of tunnel access reverted to tunnel management personnel after tunnel reentry and recoveries. Entry procedures and use of the tunnel log book were then as discussed above.

Additional access controls were instituted for radiological safety purposes after an event or during construction and event preparations when radioactivity from a previous event could be encountered. Part or all of a tunnel complex would be established as a radiation exclusion (radex) area.

All persons entering radex areas were logged on Area Access Registers by radiological safety personnel. Names and organizations represented were listed. Radiation exposures for the year were listed upon entry and added to with self-reading pocket dosimeter measurements upon exit. This was to assure that personnel approaching radiation exposure guide limits would not be allowed to enter radex areas and accumulate exposures above guide amounts.

Before entry, personnel were dressed in anticontamination clothing and respiratory protection as needed for the particular radiological conditions in the tunnel. Upon exit, anticontamination clothing was removed, personnel were monitored for radioactive contamination, and decontamination was accomplished, if necessary.

2.5.2 Drilling Area Access Control

Access to drilling areas was controlled by the drilling superintendent and the DOD Test Group Director for the same reasons as controlling access to underground workings. During drilling of an emplacement shaft, and during postevent drillback operations to recover radioactive core samples, personnel safety and compliance with safety regulations were emphasized continuously.

During preevent drilling activities, all visitors were required to contact the drilling superintendent before entry to the drilling site. Names of visitors and purposes of visits were entered in the daily drilling report, and it was assured that visitors had hard hats and understood safety regulations.

When classified materials, including the nuclear device, were brought into the area for emplacement, the DOD Test Group Director controlled access to the area with assistance from security force personnel as in similar tunnel operations. After the event, when the drill site was a radex area, during classified material removal, or during postevent drilling, both security and radiological safety access controls were in effect as discussed under Tunnel Access Control.

2.6 INDUSTRIAL SAFETY CONSIDERATIONS

Implementation of an effective industrial safety program was an important part of any heavy construction operation. Mining and drilling operations had a particularly high accident potential. These operations at the NTS involved additional safety problems resulting from detonation-induced unstable ground conditions and potential for encountering toxic gases and mixtures, and radioactivity.

Tens of miles of underground workings were constructed. More depth of big holes (three-foot diameter or larger) were drilled than the total drilled in the rest of the world. Directional and core drilling to recover radioactive debris samples after underground nuclear detonations advanced the science of these drilling techniques. These operations were accomplished under unusual conditions with accompanying difficult safety problems.

However, the lost-time accident frequency for the NTS support contractor employing most of the NTS personnel (REECo) was only one-tenth of the frequency for the heavy construction industry at large (as determined by annual surveys and reports for 300 heavy construction corporations). This excellent safety record was attained by continuing attention to indoctrinating and training NTS personnel, investigating and determining causes of accidents at the NTS, implementing and enforcing safety regulations, and, most important, maintaining the safety awareness of NTS personnel.

This was a joint effort by the DOE and DNA, and their predecessors, and by the many other government agencies and contractors at the NTS. Administered by REECo, the safety program enjoined all NTS personnel to conduct operations safely, and was exemplified by the signs on the portal of a typical DOD tunnel complex as shown in Figure 2.3, including "Safety With Production Is Our Goal."

The safety procedures for all NTS operations are voluminous and cannot be included in this report. Appendix C of this report is an example of pertinent safety procedures; General Tunnel Reentry Procedures for Department of Defense and Sandia Laboratory Tests. As these procedures indicate, several aspects of industrial safety are interrelated. Information on monitoring levels of radioactivity and personnel exposures to radiation is presented in the next section, 2.7 Radiological Safety Procedures.

Monitoring of toxic gases and explosive mixtures was an important aspect of safety in underground workings, on drill rigs, and in drillhole cellars (enlarged first part of drillhole for valving and other equipment). Toxic gases and explosive mixtures were created by both the nuclear detonations and the mining and drilling operations. The Draeger multi-gas detector and the MSA explosimeter were used to detect such gases. The Fyrite or J&W oxygen indicators were used to determine the oxygen content of the working atmosphere. Requirements were that tunnel and drill rig breathing atmosphere contain at least 19.5 percent oxygen. During the period covered by this volume, it was required that breathing air contain less than the following levels of toxic gases and explosive mixtures:

Gases	Maximum Concentration
Carbon monoxide, CO	50 ppm
Carbon dioxide, CO_2	5000 ppm
Nitric oxide plus nitrogen dioxide, $NO + NO_2$	25 ppm
Nitrogen dioxide, NO_2	5 ppm
Explosive mixtures	10% of LEL (lower explosive limit)

Procedures for controlling explosive mixtures and toxic gases after each test event are discussed in event chapters as appropriate.

2.7 RADIOLOGICAL SAFETY PROCEDURES

Procedures were developed in an effort to evaluate radiological, toxic, and other hazards, and protect workers and the public from unnecessary exposures. The following were primary written procedures and implementation methods used at the NTS from 1962 through 1965.

2.7.1 U.S. Atomic Energy Commission Nevada Test Site Organization - Standard Operating Procedure, Chapter 0524, Radiological Safety

Chapter 0524, which appears as Appendix D to this volume, defined responsibility, and established criteria and general procedures for radiological safety associated with NTS programs. Some but not all of the major areas discussed are film badge procedures, radiation surveys, entry into controlled areas and radiation exposure guides. Roles of the onsite REECo Radiological

Safety Division (Radsafe) and the offsite United States Public Health Service (PHS) also are defined in NTSO-SOP Chapter 0524.

2.7.2 Standard Operating Procedures for the Radiological Safety Division, REECo, dated January 1961

These procedures were prepared to address in more detail the radsafe aspects discussed in the latest revision of NTSO-SOP Chapter 0524. The same major areas were discussed but in a more specific manner.

2.7.3 REECo Radiological Safety Division Information Bulletins

The Information Bulletins were formalized instructions for performing specific radiological safety and industrial hygiene tasks. They defined a situation, delineated responsibility, and described methods to be used in performing the task.

2.7.4 Detailed procedures as outlined in REECo Radiological Safety Division Branch Operating Guides

These were informal internal procedures written to address a particular known or anticipated operational activity.

2.7.5 Implementation of radiological procedures required equipment, devices, and capabilities for monitoring radiation levels in the environment, and monitoring external and internal exposures of personnel.

Equipment and devices used for these purposes, and necessary capabilities were as follows:

A. Portable Radiation Detection Equipment

Eberline PAC 3G (alpha)

Eberline PAC 1SA (alpha)
Technical Associates Juno SR-3 (medium range alpha, beta, gamma)
Floor Monitor (alpha)
Floor Monitor (low range beta, gamma)
Portal Monitors (low range beta, gamma)
Beckman MX-5 (low range beta, gamma)
Eberline E-112 (low range beta, gamma)
Precision 111 (low range gamma)
Eberline E-500 (high range gamma)
Victoreen Radector (high range gamma)
Jordan AGB 10 KG SR Rad Gun (high range gamma)
UW-1, underwater (gamma)
Gateway Monitor (gamma alarm)
Nuclear-Chicago 2715 Nemo (neutron)
PNC-1 (neutron)
FN-1a (fast neutron)

B. Air Sampling Equipment

High-volume air samplers (Staplex)
Low-volume air samplers (Gelman)
Continuous and sequential samplers
Fallout and resuspension trays

C. Laboratory Analysis Capability

The radiological safety laboratory analyzed air, soil, water, surface swipe, fallout tray, nasal swab, urine, and wound swab samples for some or all of the following activities: gross alpha and beta, gross fission products, tritium, strontium-90, plutonium-239, and spectrographic analysis of specific gamma-emitting radionuclides. The laboratory also analyzed some of the above samples for nonradioactive materials, such as beryllium, through use of an emission spectrograph and by wet chemistry procedures. A spectrophotometer was used to analyze other materials.

D. Monitoring of Personnel Exposures

A DuPont type 301-4 film packet with a type 508 low range component and a type 834 high range component was used as the personnel dosimeter of record. Ranges of the two components were 30 mR to 10 R, and 10 R to 1000 R, respectively. The packet was wrapped with a 28-mil-thick lead strip covering an area one-half inch by one inch on each side.

The packet was in a four-mil-thick plastic bag. A colored tape across the top of the bag indicated validity for a given month. The bag was attached to the security badge with a clip, and security guards assured that all personnel entering NTS wore a valid film dosimeter. Film badges were exchanged routinely each month for all individuals, and upon exit from a radex area when it was suspected that an individual had received 100 mR or more of exposure.

Personnel entering radex areas also were issued self-reading pocket dosimeters which indicated accumulated exposure upon exit. Pocket dosimeter readings were entered on Area Access Registers and added to yearly and quarterly accumulated exposures from the automated daily NTS radiation exposure report. Pocket dosimeter readings were only estimates because several factors caused these readings to be less accurate than the doses of record determined after processing of film packets.

This use of Area Access Registers helped to maintain personnel exposures below the whole-body exposure guides in Chapter 0524, 3000 mrem per quarter and 5000 mrem per year. Personnel with exposures from the report plus any dosimeter reading since the report in excess of 2500 mrem per quarter or 4500 mrem per year were advised not to enter radex areas and their supervisory personnel were so notified.

2.7.6 Additional methods used for control of radex areas and to prevent spread of contamination to uncontrolled areas were as follows:

A daily log book was maintained by Radsafe monitors for each of the radex area locations. These log books were used to record the following information:

A. Work accomplished: Where people worked and what work was accomplished were briefly described. Any unusual conditions, such as equipment failure and operational difficulties, were listed.

B. Visitors: First and last names of visitors were entered. Their destination and reason for their visit were included where possible. Time they exited the area and results of personnel monitoring were recorded.

C. Unusual occurrences: Any unusual events which occurred during the shift were recorded. This entry included accidents, high-volume water seepage, or any other occurrence of an unusual nature.

D. Surveys and samples: Information collected was recorded as follows:

Survey type - Routine or Special*
Sample type - Routine or Special*
*Indicate requester's name for Special type.

E. Date and signature: The date and shift were entered at the beginning of each work period and the log book was signed before leaving the shift.

Personnel leaving radex areas removed anticontamination clothing and equipment and placed them in special containers for later laundering or disposal at the designated NTS burial site. Personnel then were monitored to assure radiation levels were below those listed on page 284 of Appendix D, NTSO-SOP Chapter 0524, Radiological Safety. Personnel decontamination was accomplished if radiation levels were above specified limits. Decontamination usually was accomplished by vacuuming, removing radioactive particles with masking tape patches, washing hands or localized skin areas with soap and water, or showering with soap and water.

Vehicles and equipment removed from radex areas were monitored to assure radiation levels were below those listed on pages 284 and 285 of Appendix D for release on the NTS. Limits for release of vehicles and equipment off the NTS were 0.3 mrad/h beta plus gamma radiation at contact and no detectable alpha activity. Vehicles and equipment normally were decontaminated by vacuuming and steam cleaning with water or detergent solutions.

2.8 TELEMETERED MEASUREMENTS OF RADIATION LEVELS

Beginning in the early 1960's, various applications of radiation measurement telemetry were developed at the NTS to determine radiation levels at critical underground and surface areas following nuclear detonations. Multi-detector systems with range capabilities from 0.5 mR/h to 500 R/h and from 10 mR/h to 10,000 R/h, continuously monitored locations of concern after being emplaced and calibrated prior to each test event. Ion chamber detectors were hard-wire-linked by telephone trunk lines to exposure rate meters at a central console in Control Point Building 2. Detector locations were as far as thirty-five miles from the console.

These remote radiation monitoring systems provided data for reentry personnel participating in radiation surveys and recovery operations after detonation of a nuclear device. The systems aided in substantially reducing radiation exposure of personnel involved in reentry programs, and were useful in detecting any venting or leaking of radioactive effluent to the atmosphere from an underground detonation.

2.8.1 Evaluation and Development of Telemetry Systems

The radiation telemetry systems developed and used had specific applications depending upon distance, terrain, environment, and operational needs. The detection units, systems, and components being studied and developed in 1962 were the following:

A. Remote Data Station (RDS)

The RDS unit was built by the National Bureau of Standards. The unit used a Geiger tube as the detecting element, and the signal was transmitted by hard wire. The DC current from the GM tube was converted to frequency by running it through an oscillator circuit, and was read out as cycles per second which could be equated to roentgen rate readings. The range of the RDS was 10 mR/h to 10 R/h. This unit was very efficient for transmitting long distances, but had limited exposure rate range and shock resistance capability. The unit was modified for use at NTS, but its use was discontinued later because the measurement range was inadequate. The application of RDS units to a telemetry system at NTS is discussed in Chapter 3.

B. Area Remote Monitoring Station (ARMS)

These units consisted of Tracerlab TA-6 (GM tube) gamma detectors with Model 261 direct readout meters. The meter had a two-range scale, 0 to 10 R/h and 0 to 100 R/h. The hard-wire system had a 35-mile transmission range, and had limited shock resistance capability. Ground shock caused failure of the units (see Chapter 3), and their use was discontinued.

C. Radector Monitoring Station (RMS)

These units had Radector portable detector electronics including the Neher-White ionization chamber used for remote radiation detection. The stations were the most versatile telemetry detectors, could transmit signals 35 miles by hard wire, afforded direct readout, and ranked highest in shock resistance. Descendants of these units were part of the Remote Area Monitoring System (RAMS) later used for most DOD underground test events.

D. Radio-Link Telemetry

This EG&G-developed system was a line-of-sight radio-linked system, transmitting the desired information on VHF frequencies from a field unit to a main control console. The ionizing radiation-induced signal was then read out as cycles per second on a signal event-per-unit-time meter. The system did not have desired range or battery life for all applications but was valuable in areas where there were no hard wires available.

E. Well Logging Unit

This unit was a Jordan ion chamber gamma detector with a glass-head thermister capable of obtaining gamma radiation measurements or temperature either separately or simultaneously, and was used at drill sites for post-event hole radiation and temperature measurements. Radiation detection ranges were from 0.5 mR/h to 500 R/h and temperature measurement ranges were from 0°F to 350°F.

2.8.2 Use of Telemetry Systems at NTS

Permanently established remote radiation detector stations could be monitored continuously at living areas, work areas, and other locations throughout the NTS after each test event. Figure 2.4 shows a typical arrangement of permanent remote detector stations located throughout NTS. Some changes in location were made when activities in some areas ceased or were renewed.

For shaft-type events, a typical array of remote detectors installed for the event is shown in Figure 2.5. Eight or more detectors were installed in circular patterns at two or more distances from surface ground zero. Detectors sometimes were concentrated in the predicted wind direction, and the distances of circular arrays from surface ground zero could be varied with the predicted yield and wind velocity.

Remote detector placement on the surface for tunnel-type events was determined by the location of stations of interest to

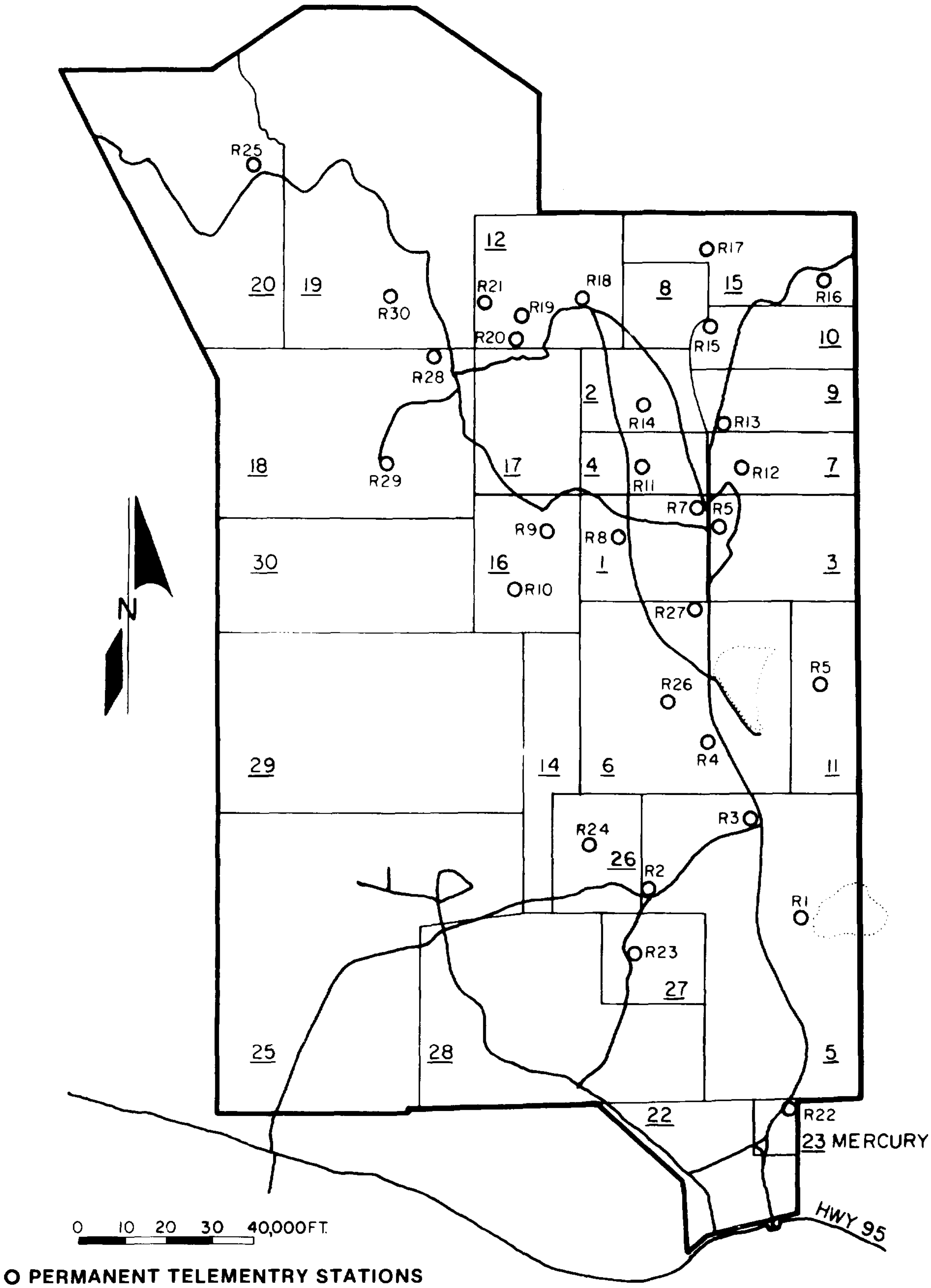

Figure 2.4 Typical Permanently Established Remote Radiation Detector Stations Operated Continuously Throughout the NTS

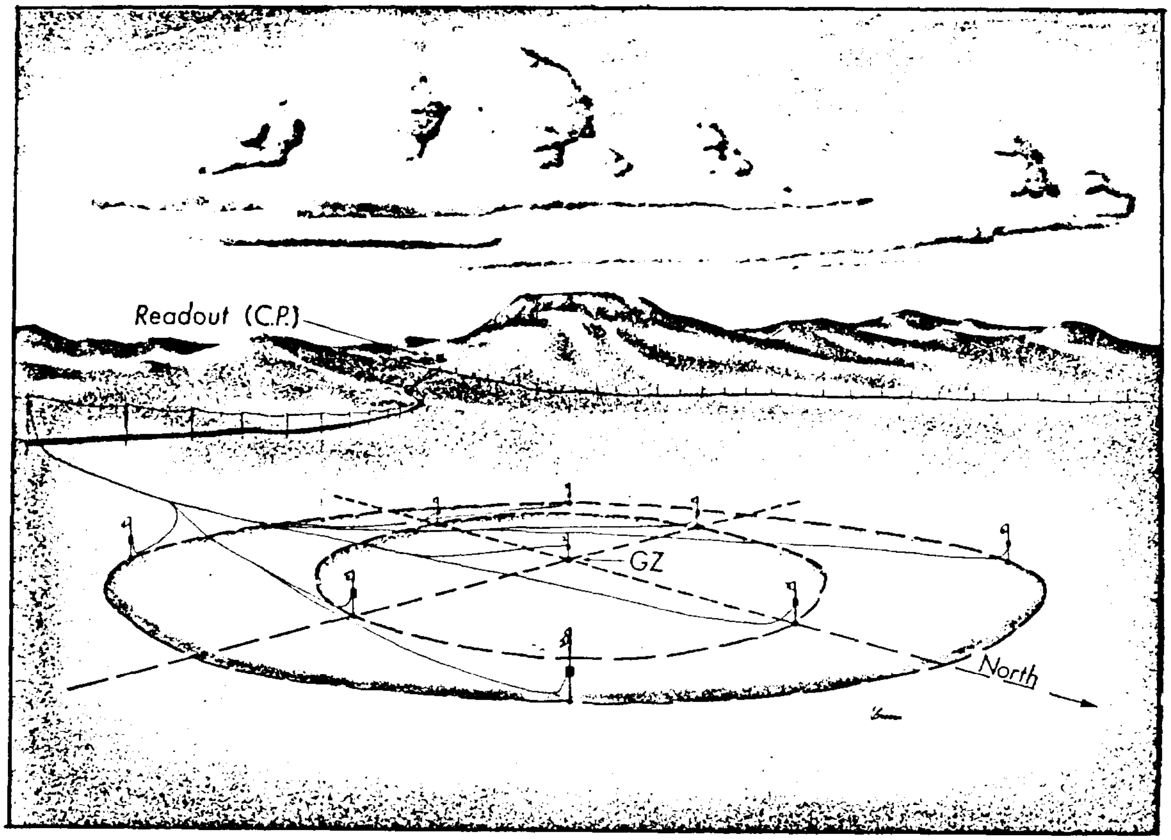

Figure 2.5 Typical Remote Radiation Detection Monitoring System for Shaft-Type Emplacement Site.

surface reentry personnel and accessible installation locations at greater distances from the tunnels. Figure 2.6 shows a typical surface remote detector array for a tunnel event. Additional detectors were located within the tunnels to provide information for tunnel reentry.

Approximately 200 detector channels were available for the permanent, shaft-type, and tunnel-type arrays. Readings from event-related and permanent telemetry detectors were recorded from zero time until it was determined that no release of radioactivity had occurred, or until any released radioactive effluent had decayed to near-background levels at telemetry detector stations.

2.9 AIR SUPPORT REQUIREMENTS

The AFSWC provided direct support to the NTSO for DOD underground tests, and other Air Force organizations provided support under AFSWC control as described in section 1.3.3 of this report. Complete Air Force support was available for the DANNY BOY event, a DOD cratering event discussed in Chapter 4 of this report, and during the remainder of 1962. However, less air support was required as the probability of venting radioactive effluent to the atmosphere decreased with development of more effective containment techniques.

2.9.1 Changes in Air Support Requirements

After 1962, Air Force cloud sampling and cloud tracking aircraft generally were not required, except for AEC cratering events where radioactive effluent clouds were anticipated. The value of analyzing particulate and gaseous cloud samples to determine characteristics of a detonation decreased. Passage of the radioactive effluent through variable amounts and tempera-

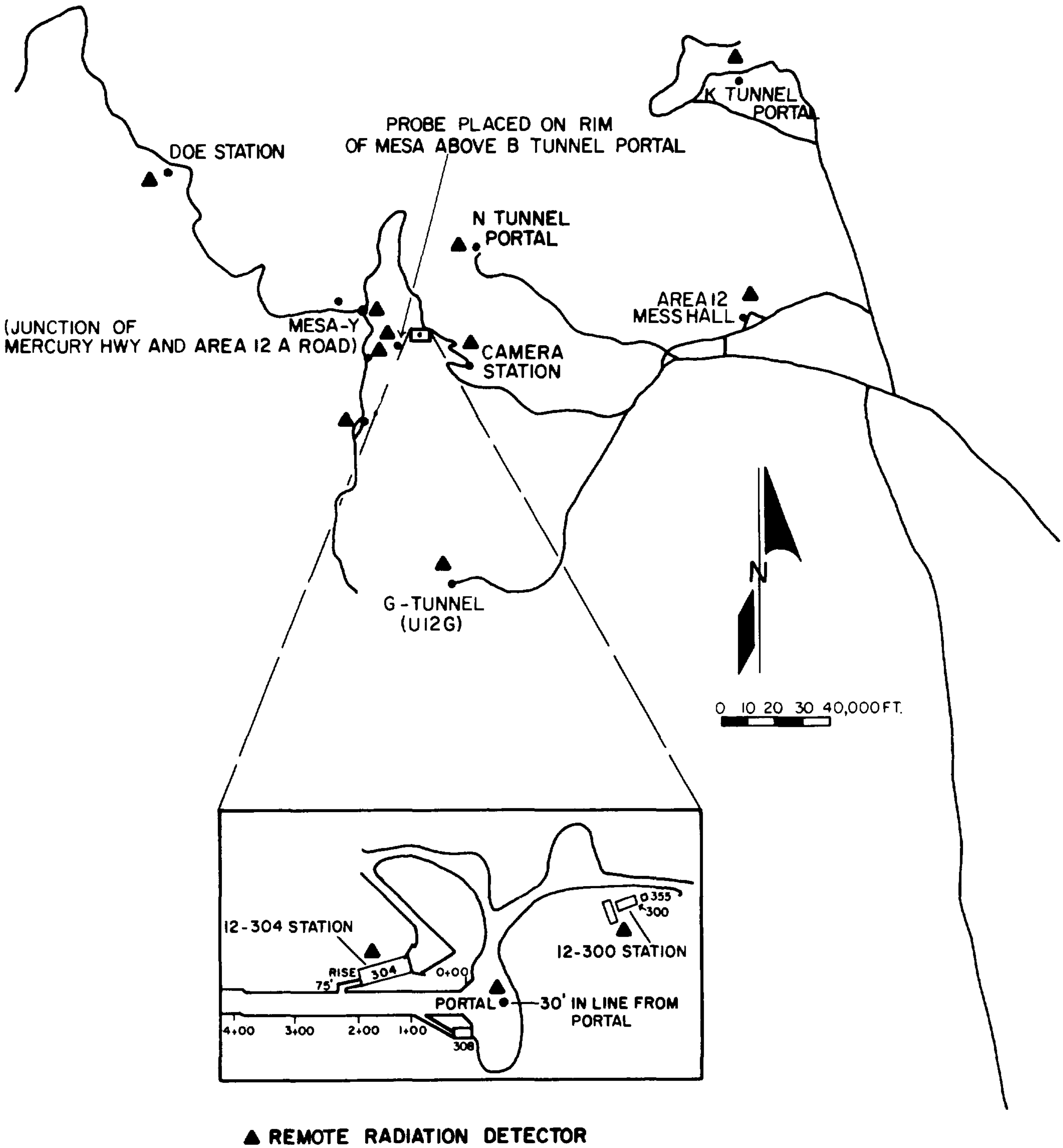

Figure 2.6 Typical Remote Radiation Detection Monitoring System for Tunnel-Type Emplacement Site

tures of rock and other media selectively retained some radionuclides underground, and changed the known ratios of fission products previously used during analysis of atmospheric detonation cloud samples.

The first change in cloud sampling and tracking support was to a lighter Air Force aircraft, the U-3A, with an Air Force pilot and PHS monitor. The PHS monitor also performed aerial monitoring of selected locations near surface ground zero and along the path of any effluent cloud. This air support later was performed by PHS and contractor personnel in their own aircraft.

The Air Force L-20 aircraft, with an Air Force pilot and a security guard from the NTS security force, continued to provide security sweep coverage of the NTS perimeter and test areas until 1968, when the type of aircraft used was changed to a helicopter. Perimeter sweeps were conducted daily, during reasonable flying weather, to assure that unauthorized vehicles were not entering the NTS over rough terrain or around security barricades on secondary roads. Air security sweeps of the immediate test area were conducted for a few hours before each detonation to assist in clearing the test area and to assure that unauthorized vehicles were not approaching it from directions not controlled by manned security stations.

Air support for photography missions during test events and initial radiation surveys after each event did not change. Helicopters and Air Force pilots generally were used with contractor photographers and Radsafe monitors.

2.9.2 Radsafe Support for Indian Springs AFB

Radsafe support facilities had been established at ISAFB during atmospheric nuclear device testing series. During 1962 tests, and subsequent DOD underground tests requiring support aircraft staged from ISAFB, REECo provided all radsafe support functions available at the NTS. This included monitors stationed at the ISAFB radsafe quonset facility, and a complete stock of film dosimeters (badges), radiation detection instruments, and anticontamination clothing and equipment for use by aircrews and ground crews.

Radsafe monitors issued and exchanged film dosimeters (badges), issued self-reading pocket dosimeters, dressed Air Force personnel in anticontamination clothing, provided respiratory protection equipment, monitored aircraft and personnel after events, decontaminated personnel, and assisted ground crew personnel with decontamination of aircraft.

Figures 2.7 through 2.9 show decontamination and monitoring of typical B-57 cloud sampling aircraft used from 1962 until the type of sampling aircraft was changed.

Aircrews departing from contaminated aircraft removed anticontamination clothing and equipment at the radsafe facility, showered, and were monitored to assure complete decontamination before they dressed in regulation clothing and were released. Ground crews who removed particulate and gaseous cloud sample collection media from aircraft or who participated in aircraft decontamination were subject to the same personnel decontamination procedures.

2.9.3 Radsafe Support for Helicopters

Although ISAFB radsafe support extended to all participating aircraft, special helicopter radsafe procedures were implemented because these aircraft landed at NTS and staged from helicopter pads located east of Mercury Highway at the Control Point area and near a Test Director's Forward Control Point (FCP) established for a particular underground event. Helicopter pilots

Figure 2.7 Air Force Personnel Decontaminating a B-57 Cloud Sampling Aircraft

Figure 2.8 Air Force and Radsafe Personnel Monitoring a B-57 After Decontamination

Figure 2.9 Radsafe Monitor Measuring Exposure Rate on a B-57 Aircraft

usually landed at these locations, and were briefed at the Control Point or particular Forward Control Point regarding their scheduled missions or other operational missions.

If the mission involved possible contamination of the aircraft, Radsafe monitors lined the floor of the aircraft with plastic, or kraft paper, and masking tape to facilitate decontamination. Pilots and crew members were dressed in anticontamination clothing and provided with film badges, pocket dosimeters, and respiratory protection equipment if airborne radioactive material was anticipated.

Upon completion of missions, helicopters returned to the landing pads where they were decontaminated by Radsafe monitors. Pilots and crew members were decontaminated at an adjacent forward Radsafe base station, or at Control Point Building 2 where pocket dosimeters were collected and read, and film badges were exchanged if exposures of 100 mR or more were indicated by pocket dosimeters.

CHAPTER 3

HARD HAT EVENT

3.1 EVENT SUMMARY

The HARD HAT event was a DOD underground nuclear detonation with a yield of 5.7 kt conducted at 1000 hours Pacific Standard Time (PST) on 15 February 1962 at shaft site U15a in Area 15 of the NTS. The device was emplaced in a 36-inch diameter shaft drilled in granite at a depth of 943 feet below the surface elevation of 5,114 feet Mean Sea Level (MSL). Cavity collapse occurred approximately eleven hours after device detonation. Minor amounts of radioactive effluent were released after cavity collapse and were detected onsite only.

HARD HAT was primarily an underground structures program with instrumentation in a nearby access shaft and tunnel complex. The purpose of the HARD HAT event was to test capability of underground structures to withstand strong motions generated by an underground nuclear detonation in hard rock. There were 25 DOD scientific projects conducted by government agencies and contractors.

Work necessary to conduct these projects included constructing an 800-foot-deep access shaft 800 feet southeast from the device emplacement shaft; constructing a 600-foot tunnel leading from the access shaft toward the emplacement shaft; constructing three arcuate test drifts intersecting the tunnel; drilling 21 holes from the underground complex; and drilling eight holes about 1,000 feet deep from the surface. Figure 3.1 is a photo of the access shaft headframe and surrounding structures, and Figure 3.2 is a sketch of the underground complex.

Figure 3.1 HARD HAT Access Shaft Headframe

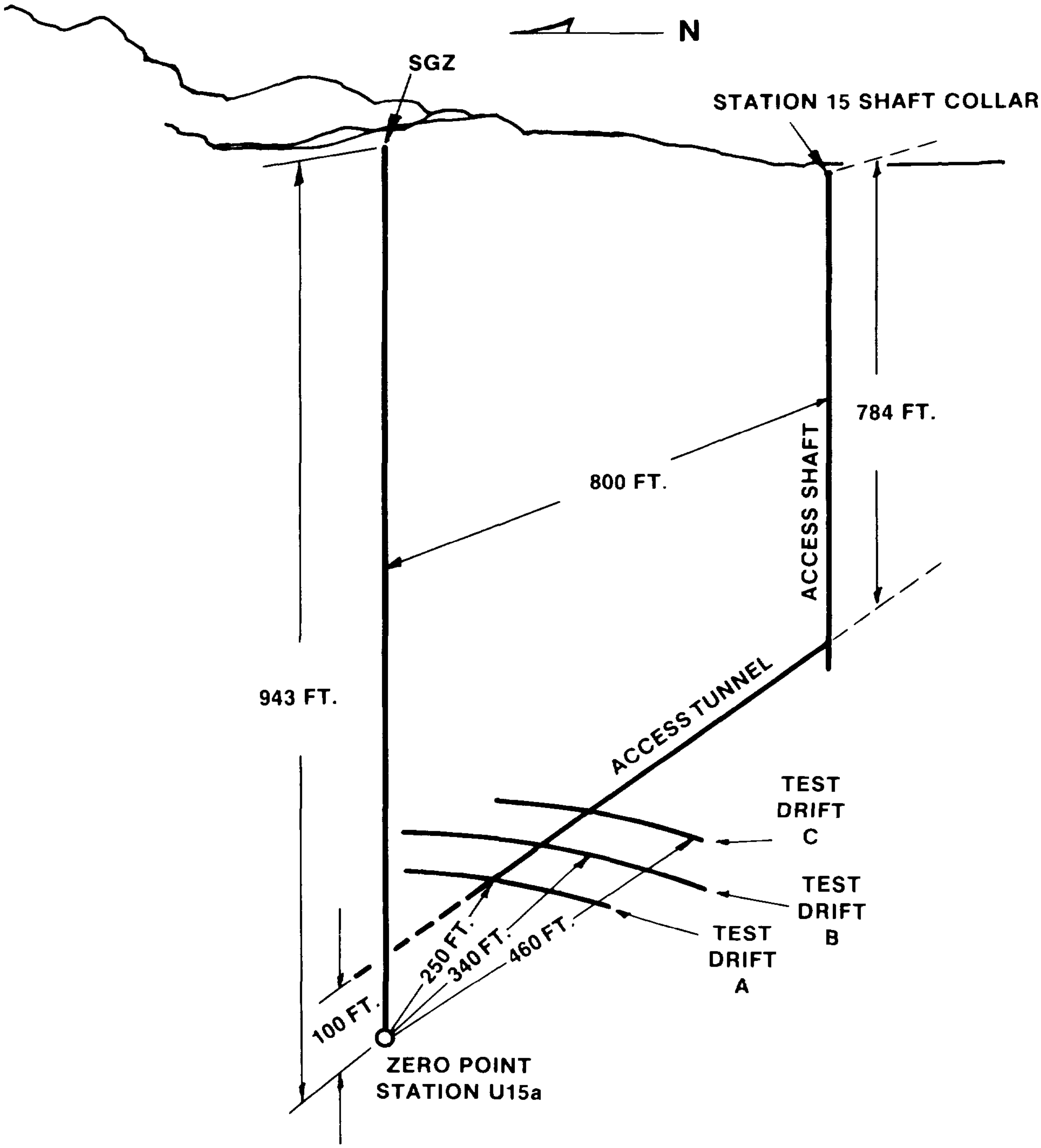

Figure 3.2 HARD HAT Underground Complex

3.2 PREEVENT ACTIVITIES

3.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all HARD HAT project activities in Area 15. Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Field Command, DASA, and the AEC Albuquerque Operations Office. SC was responsible for providing, emplacing, and arming the device, and stemming and installation of necessary measuring devices and equipment. SC and LASL were responsible for radiochemical analysis to determine yield. EG&G was responsible for providing and installing timing and firing circuits. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

3.2.2 Planning and Preparations

Project materials and equipment installed included 48 structural test sections and 450 gauges in the underground complex, instruments in 21 underground and eight surface holes, and numerous seismic and other scientific stations on the surface. The majority of measurements had to be obtained or recovered during several weeks of postevent access to the structures. These experiments were not radiation sensitive, but reentry had to be accomplished within five weeks to prevent losses due to corrosion.

The "HARD HAT Reentry Plan" described preevent preparations and postevent procedures used to assure safe and economical reentry within the desired five-week period. Stemming design in access tunnels incorporated necessary provisions to maximize safety of reentry. Geophones were installed to monitor cavity activity and assure collapse before reentry.

There were to be five separate reentry teams, each of which had a separate and specific mission:

Team 1 - Surface Radiation Survey Party
Team 2 - Shaft Collar Group
Team 3 - Shaft and Tunnel Reentry Party
Team 4 - Rescue Team
Team 5 - Working Party

Recall of the reentry teams could be made for any of the following circumstances:

1. any break in communications between Team 2 and Team 3,
2. by request of the Test Group Director or Reentry Chief,
3. upon decision of the Chief of Shaft and Tunnel Party, and/or
4. when any member of Team 3 indicated a McCaa (breathing apparatus) oxygen supply of less than 30 atmospheres.

Reentry was not to be made before the ventilation system had been turned on and samples of air monitored at the remote blower, or later at the shaft collar. Reentry was not to be made beyond the ventilated area in the shaft.

A remotely-controlled blower was installed on the surface during preevent button up at a distance of approximately one-half mile from the shaft, and a line run along the ground to the shaft collar. This line was connected by a flexible coupling to the vent pipe at the shaft collar. Remote controls for the blower were located in the Forward Control Point. A single line was run from a single blower in the shaft collar area down the shaft and tunnel, with junctions at the "A","B", and "C" arcuate drifts for short branches into the wings of the drifts.

Air sampling pipes were installed through both the sandbag plugs and the gas seal door prior to the event. These were to be used during reentry to determine breathing atmosphere conditions just forward of the plugs and door. A two-inch diameter flexible hose was installed and anchored in the "B" and "C" arcuate drifts. Compressed air was to be pumped through these drifts to clear any gases before tunnel reentry. The hose was designed for simple connection to compressed air lines.

A. Radiological Safety Support

Detailed radiological safety reentry plans were submitted to participating agencies prior to the event. Test area maps with appropriate reference points were prepared. Reference stakes, fallout trays, radiation decay recorders, air sampling equipment, film dosimeter packets, and other dosimetric devices were positioned in the test area. Reentry routes into the test area were established during "dry runs." Party monitors were briefed regarding reentry, sample recovery, manned stations, and security station requirements.

Radsafe had 12 personnel stationed at the DOD Test Group Director's FCP prior to the HARD HAT detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment, portable instruments, and self-reading dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination as required. All personnel at manned stations were provided with appropriate anticontamination clothing and equipment, and Radsafe monitors were in attendance.

Anticontamination materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

B. Telemetry Support

A radiation telemetry system was installed with the readout located in CP-2. Telemetry readout data were to be relayed to CP-1 and the FCP by telephone and network (net) 3 radio. SC and Radsafe personnel placed five ARMS units at the following surface locations:

1. 100 feet north of Surface Ground Zero (SGZ)
2. Radiochemical sampling pot number 1 (25 feet northeast of SGZ)
3. 300 feet east of shaft collar
4. Trailer number 82 (about 3,000 feet southeast of SGZ)
5. Stake L-67 (about 2,000 feet southeast of SGZ)

Radsafe personnel installed five RDS units underground and on the surface as follows:

1. In the B6A section of "B" drift
2. Station 4+65 (465 feet from shaft) in the main tunnel (at the intersection with "B" drift)
3. Station 0+40 (inner side of gas seal door)
4. Station 0+35 (outer side of gas seal door)
5. West of shaft collar on the surface

C. Security Coverage

At six hours prior to device detonation, security personnel established test area control and muster stations. The Forward Control Point and muster station for Area 15 were established about four miles southwest of

SGZ on the Circle Road between Area 8 and Area 10 (see Figure 1.5). In addition, four security stations were established to control roads leading to Area 15. A screening station was set up near the FCP at the observer area. The final security sweep of all closed areas was completed three hours prior to device detonation. U.S. Air Force (USAF) and security personnel completed a final sweep of Areas 8, 10 and 15 by 45 minutes before zero time.

D. Air Support

An Air Force U-3A aircraft, pilot, and co-pilot were made available to a PHS Aerial Monitoring Team for cloud tracking purposes. According to the PHS offsite report for HARD HAT, the principal instrument used was a Precision Model 111 scintillator, with an added transistorized amplifier feeding an Esterline-Angus strip-chart recorder, and having a maximum range of 5 mR/h in six scales.

Approximately one hour prior to device detonation, USAF and LRL personnel in an Air Force H-21 helicopter took an upwind position from SGZ in readiness for event photography coverage. In addition, approximately 15 minutes prior to device detonation, the U-3A aircraft departed from ISAFB to orbit over Frenchman Lake (Area 5) in readiness for cloud tracking, if required.

3.2.3 Late Preevent Activities

On 14 February 1962 (D-1 day), U.S. Coast & Geodetic Survey (USC&GS) personnel made final adjustments to instruments at eleven seismic stations. These were located at distances ranging from 2,400 to 8,400 feet from SGZ. LRL personnel checked electronic recording instruments and performed dry runs at Trailer 39 which was located about 2,000 feet from SGZ. SC personnel checked out instrumentation in their diagnostic trailers located about 3,000 feet from SGZ. Four DOD personnel calibrated equipment in the area from SGZ out to approximately 2,000 feet in all directions, and participated in dry runs. DOD personnel also calibrated equipment and participated in dry runs in the tunnel complexes and at SGZ. SC personnel emplaced high explosives (HE) for microbarograph calibration shots.

A Test Manager's weather briefing was conducted at 2200 hours on 14 February 1962. At this briefing, panels of administrators and experts reviewed weather forecasts, studied the projected path of any radioactive effluent, and decided that conditions were favorable for conducting the event as scheduled.

3.3 EVENT-DAY AND CONTINUING ACTIVITIES

On D-day, from midnight to three hours before scheduled device detonation, DOD personnel activated recording station equipment, checked moisture probes, started magnetic tapes, and assured operation of surface telemetry units. During this same time period SC personnel activated equipment, armed microbarograph calibration shots, and proceeded to U15a for device arming.

The final weather briefing for the Test Manager and Advisory Panel was conducted two hours prior to planned device detonation. At this time, SC personnel requested and received permission from the Test Group Director to arm the device.

Required countdowns began on radio nets 1, 2, 6, and 8. At ten minutes prior to device detonation the siren on the CP-1 building ran for 30 seconds, and the red lights on top of the building were turned on until after detonation time.

HARD HAT zero time was 1000 hours on 15 February 1962.

Underground telemetry units in the "B" drift and in the main tunnel 465 feet from the shaft failed to respond after zero time because lines were damaged. Remaining telemetry units underground and on the surface did not detect radiation intensities above background from device detonation through 1630 hours when telemetry readouts were secured.

Two microbarograph calibration shots were scheduled to be fired at five and eight minutes, respectively, after zero time. One microbarograph shot misfired but the problem was corrected and the shot was fired two hours after device detonation.

A USAF/PHS aerial monitoring team entered the area 40 minutes after device detonation. Aerial monitoring was conducted from one mile to 15 miles downwind for the next 45 minutes. Results of aerial monitoring indicated no measurable release of activity immediately following the event.

Two Radsafe initial survey teams in vehicles were released by the DOD Control Officer at 1200 hours after the second microbarograph shot. Ground radiation surveys were made both at fixed locations and during sweeps through the area. One of the sweeps was a 360-degree circuit of SGZ at a radius of 100 feet. No measurement indicated radiation above background. The three radiochemistry sample collection pots on the sampling pipe from SGZ to 50 feet northeast of SGZ read background, and survey monitors reported the lids were off the pots. Apparently, the detonation or pipe closure devices closed the pipe before effluent samples were obtained. Industrial hygiene sampling measurements made during the radiation surveys indicated no detectable concentrations of explosive mixtures or toxic gases.

At approximately 1315 hours, the DOD Control Officer proceeded into Area 15 and established an FCP approximately 200 feet southeast of the shaft collar. At this time, the Radsafe check station trailer was moved to within 150 feet of the shaft on the east. The two Radsafe survey teams were left at the newly established FCP to act as monitors for recovery parties, with instructions that no personnel were to enter within 100 feet of the SGZ area unless specifically authorized by the DOD Control Officer or a delegated representative.

Recovery of experiment data on the surface in the test area continued for several hours. Radiation measurements made by party monitors were not above background, radex areas were not established, and film badges were not exchanged upon exit from the test area. At 1600 hours, after statements by test personnel that the detonation apparently was contained, the DOD Control Officer delegated area control to security force and Radsafe personnel with no special instructions. Telemetry readouts were secured by Radsafe at 1630 hours. All recovery personnel were clear of the test area by 1800 hours, and the Radsafe monitor in the SGZ area moved back to the security roadblock at the junction of the shaft and SGZ access roads about 700 feet south of the shaft. Also at this time, the monitor at the Radsafe checkpoint secured the trailer and left the area.

The Radsafe monitor at the security roadblock drove to the shaft to make a survey at 1930 hours. He detected no CO, CO_2, NO, NO_2, hydrocarbons, or explosive mixtures. However, he detected 18 mR/h at the flexible coupling to the shaft vent pipe. At 2010 hours, he again detected 18 mR/h at the shaft, but no radiation above background at the security roadblock.

At 2053 hours, the Radsafe monitor and the security guard reported hearing two rumbles from the SGZ area but felt no ground movement. The underground detonation cavity had collapsed. The roadblock was moved 200 feet farther south as a precautionary measure, and the Radsafe supervisor arrived at 2120 hours. The two Radsafe personnel proceeded to the shaft collar and measured 100 mR/h and no toxic gases or explosive mixtures at 2155 hours.

A pungent odor was detected as they drove toward SGZ. They retreated and approached SGZ from upwind. After measuring 50 mR/h at the SGZ plug, and no CO or CO_2, they quickly left the area to avoid the pungent odor.

Another survey of SGZ was made at 0130 hours on 16 February. The maximum reading was 500 mR/h near the SGZ plug base. No CO or explosive mixtures were detected, but sulfurous odors were noted in the area. Several fissures in the SGZ area read background.

At 0630 hours, the plug base still read 500 mR/h, and a 40-foot-long fissure read 200 mR/h with 200 ppm CO_2, 400 ppm CO, and no detectable explosive mixtures. Radioactive gases displaced by cavity collapse apparently were coming up the radiochemical sampling pipe. A measurement inside sample pot number 2 indicated 10 R/h, and three feet from the pot the reading was 100 mR/h. Exposure rates in areas not near fissures or sample pots averaged about 10 mR/h.

A survey of the shaft collar area at 0715 hours indicated vent line contact and general exposure rate readings of 6 mR/h maximum. The security roadblock continued to assure that only Radsafe personnel entered the area.

Operation of the radiation telemetry system resumed at 0815 hours. Surface units continued to indicate less than the detectable 10 mR/h. Apparently, the unit 100 feet north of SGZ failed to detect the gaseous radioactivity or malfunctioned, and the unit near sample pot number 1 malfunctioned, because both continued to indicate no positive readings. A survey of SGZ at 0900 hours indicated nothing above background at the fissures, but 8 R/h at contact with sample pot number 1.

Table 3.1 shows readings from the functioning underground telemetry units. Gaseous radioactivity displaced by cavity collapse apparently had been forced through fissures into the underground tunnel complex. Maximum readings were greater than 10 R/h inside the gas seal door, and 160 mR/h outside the door.

A PHS aerial monitoring team arrived over SGZ at 1050 hours. Aerial monitoring indicated a continuing release sustaining a field north of SGZ. One-quarter mile north of SGZ an increase in radiation was noted with a peak of 0.15 mR/h gamma above background three-quarters of a mile north of SGZ. The release appeared to be contained in the atmosphere below the clouds.

Three miles north-northeast of SGZ the cloud was in the form of two fingers, each one quarter of a mile wide, with peak gamma readings of 0.03 mR/h above background. From this point out to eight miles from SGZ, readings of approximately twice background were detected. No radiation levels above background were detected outside NTS boundaries.

At the direction of DOD representatives, Radsafe personnel installed a rope barricade around SGZ at a radius of about 70 feet. Radiation warning signs were affixed to the barricade, and the task was completed by 1200 hours. The same type of barricade then was installed around the shaft collar area.

Exposure rates at SGZ decreased during the day. By 1430 hours, maximum personnel exposure rates were less than 100 mR/h, and by 1715 hours, less than 10 mR/h with no toxic gases or explosive mixtures detected. Readings at contact with sample pot number 1 decreased to 100 mR/h at 2200 hours. By 0700 hours on

TABLE 3.1

HARD HAT EVENT

TELEMETRY MEASUREMENTS INSIDE OF TUNNEL
(Gamma Radiation in R/h)

DATE	TIME (PST)	STATION 0+40	STATION 0+35
	Station B6A and 4+65 did not respond after zero time. Underground stations did not read above background from zero time until telemetry was secured at 1600 hours on 15 February 1962. Readings after telemetry was resumed as follows (Station 0+40 was inside and Station 0+35 was outside the blast door):		
16 Feb 62	0815	>10.0	0.160
	0830	>10.0	0.155
	0845	>10.0	0.143
	0900	>10.0	0.135
	0930	>10.0	0.140
	0945	>10.0	0.135
	1000	>10.0	0.125
	1015	>10.0	
	1030	>10.0	0.115
	1045	>10.0	
	1100	>10.0	0.105
	1115	>10.0	
	1130	>10.0	0.096
	1200	>10.0	0.082
	1230	>10.0	0.082
	1315	>10.0	0.070
	1400	>10.0	0.050
	1500	>10.0	0.038
	1600	>10.0	0.030
	1700	>10.0	0.018
	1800	>10.0	0.020
	1900	>10.0	0.019
	2000	>10.0	0.0165
	2205	8.90	
17 Feb 62	0010	7.80	0.0105
	0325	6.10	0.01
	0600	5.00	
	0620	4.60	
	0700	4.20	
	0730	4.10	
	0800	3.90	
	0900	3.70	
	0930	3.30	
	1000	3.30	
	1100	3.00	
	1200	3.00	
	1300	3.00	
	1400	3.00	

TABLE 3.1 (Concluded)

DATE	TIME (PST)	STATION 0+40	STATION 0+35
	1600	2.00	
	1650	2.10	
	2130	1.45	
	2230	1.30	
	2336	1.20	
18 Feb 62	0010	1.10	
	0147	1.00	
	0740	0.52	
	0900	0.44	
	1000	0.38	
	1100	0.33	
	1300	0.28	
	2030	0.178	
	2330		
19 Feb 62	0320	0.155	
	0400	0.14	
	0800	0.12	
20 Feb 62	0800	0.085	
	2000	0.054	
21 Feb 62	0800	0.052	
	1600	0.052	
22 Feb 62	0800	0.041	
23 Feb 62	0500	0.038	
	2100	0.030	
24 Feb 62	0730	0.026	
25 Feb 62	1500	0.025	
26 Feb 62	0830	0.024	
	1900	0.024	
27 Feb 62	0800	0.022	
	1630	0.02	
28 Feb 62	0800	0.017	
1 Mar 62	0800	0.016	
2 Mar 62	0800	0.014	
3 Mar 62	0800	0.011	
4 Mar 62	0800	0.01	

17 February, general exposure rates at SGZ were less than 5 mR/h and at the shaft collar were less than 0.5 mR/h.

3.4 POSTEVENT ACTIVITIES

Each area was marked to indicate particular radiation levels, as were all contaminated and radioactive materials. Personnel entering radiation areas or working with contaminated material were briefed concerning potential exposure and safety precautions, and provided with anticontamination clothing, equipment, and materials.

Decontamination units were positioned at entrances to controlled radiation areas. Personnel and equipment were monitored and decontaminated as necessary. Drill rigs and associated equipment used in postevent activities also were monitored and decontaminated as necessary.

After use, anticontamination clothing and equipment were laundered and returned to stock for subsequent reissue. Items which could not be decontaminated to permissible levels were buried at a designated disposal site.

Industrial hygiene and radiological surveys were performed under the direction of the DOD Test Group Director in accordance with the "Radiological Safety Support Plan for HARD HAT."

3.4.1 Postevent Drilling

Because the radiochemical sampling system failed to obtain a radioactive debris sample for yield determination analysis, postevent drilling operations to obtain a core sample from the solidified radioactive melt rock became even more important. The first drill rig was moved in and began setting up outside the barricaded SGZ area at 1630 hours on 16 February. Investigation of holes predrilled toward GZ before the test event revealed damaged and unusable casing 30 feet below the surface.

On 18 February, two rigs were setting up in the SGZ area. One rig commenced drilling 20 feet east of the SGZ plug at 1550 hours 19 February. Up to three drill rigs were used at once during attempts to obtain samples of solidified melt. Drilling through the hard, fractured granite was slow and difficult. However, a depth of 675 feet was reached by 2140 hours 24 February when return drilling mud read 5 mR/h. This reading indicated the cavity boundary was being approached or had been entered by the number 1 drill rig.

At 2210 hours, the drill stem and bit stuck in the bottom of the hole. After pumping diesel fuel into the hole, drillers used a 90-ton crane in conjunction with the rig to pull the stem and bit loose by 1100 hours the next morning. After reaming the bottom 150 feet of hole by 2015 hours, drilling started again, but mud circulation immediately was lost in the hole. Water trucks brought more water, more mud was mixed, and drilling resumed at 2120 hours. At 2300 hours, the drill stem fell into the remaining top of the cavity from 680 feet to 690 feet, and mud circulation again was lost.

Drilling through the cavity rubble was extremely difficult. Voids, lost mud circulation, stuck drill stem and bits, collapse of hole sides, cementing and redrilling, and lost drill bits were some of the difficulties encountered. High winds which threatened to topple the drill rig necessitated using guy wires for support. Drilling through rubble and obtaining a satisfactory core sample of melt rock required a continuing intensive effort until 8 May 1962 when the drilling operation was secured.

The maximum contact reading was 2.5 R/h on a core sample taken from the hole at a depth of 985 feet on 5 May. The second highest reading was 1,800 mR/h on a sample taken from a depth of 999 feet. The maximum toxic gas measurements were 7 ppm H_2S (the sulfurous odor, 10 ppm permissible) at the drill collar on 19 April with a depth of 897 feet, and 200,000 ppm CO_2 under the turntable at the hole opening on 23 April (this concentration diffused to a few hundred ppm at breathing level). Measurements of other toxic gases and explosive mixtures were below permissible limits.

3.4.2 Shaft Reentry

By 1330 hours on 17 February, radiation readings in the shaft collar area were background, no toxic gases or explosive mixtures were detected, the underground telemetry unit outside the gas seal door indicated less than the detectable 10 mR/h, and the shaft exhaust fan was turned on. Negative measurements continued through the night.

The only positive readings on 18 February were traces of CO and CO_2 detected from the vent line at 0630 hours. The elevator was raised from the bottom of the shaft with auxiliary power at 1345 hours on 19 February, and difficulty was experienced with binding elevator guides. Radiation measurements in the shaft collar area continued to be negative.

At 1135 hours on 21 February, shaft reentry preparations began with electricians reconnecting power transformers to feed the shaft collar area. Radiation, toxic gas, and explosive mixture measurements continued to be negative, but personnel working around the shaft collar were required to wear anticontamination clothing and respiratory protection as a precautionary measure.

The hoist, headframe, and shaft signal system were examined for safe operation. To aid this determination, a dummy load of

2,500 pounds plus a weight equal to the regular elevator was prepared for lowering to the bottom of the shaft. From 1430 to 1500 hours on 22 February, the small personnel elevator loaded with lead bricks was lowered to the bottom of the shaft and returned to the surface. A maximum contact reading of 0.5 mR/h on the elevator decreased to 0.1 mR/h within five minutes, indicating trapped radioactive gases which dispersed rapidly.

Electricians reconnected power for the second shaft vent line blower at 0800 hours on 23 February, and the vent line was in service by 1030 hours. Before any personnel entered the shaft, a check was made of all electrical and phone lines going into the shaft to insure they were locked open. All switches locked out during button up were rechecked. A special check was made to assure all sources of electrical power into the shaft were locked out prior to reentry. Initial reentry and inspection personnel would have their own communication line lowered with them.

To insure that personnel could be removed from the shaft should conditions prevent return of the inspection cage to the surface, the following equipment was available at the shaft collar:

1. standby hoist with sufficient cable to reach the bottom of the shaft and capable of lifting 3000 pounds,

2. two bosun chairs with chest straps, and

3. wire litter with straps.

Because the shaft guides for the large elevator were damaged, a change to the reentry plan was made and the small personnel elevator with only two personnel was used for initial shaft inspection. At 1330 hours on 23 February an LRL representative and a REECo mining superintendent in full anticontamination clothing and self-contained breathing apparatus descended in the shaft. The speed of descent of the inspection cage was extremely slow. The cage moved only when inspection of shaft ventilation indicated further descent was prudent. They reached the bottom at 1445 and returned to the surface at 1510 hours. Radiation readings were less than 1 mR/h on gloves and their communication wire.

Shaft repair began on 24 February with work on the elevator cage, replacement of elevator guides, and repair of sets and lagging from the surface down. By 2 March, the shaft was repaired to a depth of 190 feet; by 5 March to a depth of 340 feet; by 7 March to a depth of 600 feet; and by 8 March, repairs were complete. Only background radiation and traces of CO and CO_2 were encountered during shaft rehabilitation.

3.4.3 Tunnel Reentry

An inspection party was lowered in the shaft on 10 March at 0945 hours to examine the lower drift and the steel gas seal door at Station 0+37 (37 feet in from shaft). All personnel were wearing anticontamination clothing and self-contained breathing apparatus. Miners attached the shaft vent line to the drift vent line with a two-foot section, opened the valve, and the party returned to the surface. Vent fans were turned on at 1032 hours, and measurements of 1 mR/h and 2,000 ppm CO_2 in the exhaust decreased to near-background levels by 1200 hours.

The tunnel reentry party was back in the shaft at 1210 hours, this time without breathing apparatus, samples taken from sampling pipes through the gas seal door indicated safe conditions, and miners cut open the door. By 1536 hours on 10 March, the entry party advanced in the tunnel to the end of ventilation. No toxic gases, explosive mixtures, or radiation above background were encountered, and no contamination was detected on exiting party personnel.

Subsequent reentry teams equipped with self-contained breathing apparatus explored ahead of ventilation. During pre-event button up, the branches in the arcuate drift wings and the entire ventilation system from Station 4+10 (410 feet in from the shaft) forward had been removed. Also, twenty-foot sections were removed at "C" drift and Station 0+87 (87 feet in from shaft). All vent pipe removed was stored in the tunnel for reinstallation on reentry.

Miners repaired track, mined through and removed rock and debris from collapsed tunnel areas, removed sandbag plugs, and replaced ventilation lines. Radsafe monitors routinely checked for CO, CO_2, NO, NO_2, hydrocarbons, explosive mixtures, and radiation. If readings exceeded permissible limits for toxic gases or 10 percent of the Lower Explosive Limit (LEL) for explosive mixtures, reentry was to be suspended until ventilation improved conditions. Toxic gases and explosive mixtures were to be expected as a result of both the nuclear detonation and blasting during reentry operations. Explosive mixtures up to 50 percent of the LEL, CO levels up to 750 ppm, and $NO+NO_2$ concentrations up to 10 ppm were encountered during reentry and mining operations. The maximum radiation measurement encountered was 5 mR/h in the center of the track 308 feet from the shaft.

Miners encountered considerable difficulty removing muck (broken rock) and other debris from collapsed tunnel sections. Blasting was necessary to loosen pipe and reinforcement steel in addition to collapsed granite. Broken rock in the tunnel back (ceiling) had to be supported with steel sets and lagging (2 x 8-inch boards forming a solid ceiling between upright sets). In some portions where rock would fall in at the same rate it was being mucked (removed), timbers had to be driven through the broken rock along the tunnel back for support to make headway.

Progress was slow. At 1400 hours on 18 April, the miners broke through into the "B" drift. Center line of the newly mined main tunnel through broken rock was five feet west of center line for the old main drift at the intersection with the "B" drift. Measurements indicated 0.1 mR/h and no toxic gases or explosive mixtures. A bypass drift around the badly damaged first two test sections of "B" drift was started 23 April. A nitrous odor was detected after blasting. Toxic gas testing indicated no detectable CO, $NO+NO_2$, SO_2, CS_2, hydrocarbons, or explosive mixtures, and only 250 ppm CO_2.

On the evening of 27 April, a noxious odor described by miners as an "ammonia smell" was experienced during slushing operations. Checks were made for gas concentrations with results indicating no CO, SO_2, or NH_3 (ammonia gas); less than 250 ppm CO_2; less than 0.5 ppm $NO+NO_2$; 18 percent oxygen in the bypass drift; and 20 percent oxygen in the main drift. However, the DOD representative in charge determined that no miners would be allowed to work in the affected area so long as the odor persisted. The odor recurred at varying times during the reentry operations, but other than occasionally causing headaches and some nausea, no other ill effects were noted. Headaches and nausea are not uncommon among miners, particularly when drifts are entered after blasting and before ventilation has cleared the dynamite fumes - particularly CO, CO_2, and $NO+NO_2$. However, the cause of the odor and the headaches was not identified, though all available Draeger multi-gas detector tubes for toxic gases were used to sample the breathing air.

"A" lateral was reached the morning of 31 May at 572 feet from the shaft. The radiation level was less than 0.1 mR/h and CO_2 was 1,000 ppm. All other tests for toxic gases and explosive mixtures were negative. By 5 June, mucking operations, and cutting torch operations for reinforcing rods, had cleared the "A" drift for access and inspection. The maximum exposure rate encountered was 0.15 mR/h.

Mining equipment was removed from the tunnel on 6 June. Final DOD-AEC inspections of the test structures were conducted on 7 and 8 June, a bulkhead over the shaft was completed, and U15 shaft and tunnel were secured at 1515 hours on 8 June.

3.4.4 Cavity Mining and Drilling

Interest in dimensions of the HARD HAT cavity and characteristics of cavity rubble resulted in reentry of the HARD HAT underground complex in early December 1962. A survey of the tunnel complex indicated 0.05 mR/h maximum, and no toxic gases or explosive mixtures.

Removal of water and mud from the elevator pocket at the bottom of the shaft was accomplished. Inspections of underground workings, general cleanup, and surveying distances relative to GZ and the cavity were completed by 17 December when mining operations commenced without radex (radiation exclusion) area requirements (anticontamination clothing and equipment or pocket dosimeters).

Mining was intended to penetrate the cavity rubble to GZ, obtain rubble rock fragments for evaluation, and determine distribution of fragment sizes. Core drilling from the tunnel complex was intended to outline the cavity and provide samples for analysis of mineral characteristics.

Tunneling reached the chimney of broken rock, which indicated the cavity boundary, on 7 January. General exposure rates near the face were 1 to 5 mR/h on 9 January 1963, and radex area procedures were not required. No explosive mixtures and only minor amounts of CO_2 had been detected in the mining operations.

Labor strife at the NTS caused delays in mining operations until 14 February. Personnel going underground then were equipped with anticontamination gloves, boots, and pocket dosimeters, and use of Radsafe Area Access Registers was implemented. These limited radex area requirements were implemented because general exposure rates near the tunnel face were increasing. By 26 February, the maximum reading at the face was 8 mR/h, and the general exposure rate at the face was 6 mR/h with no toxic gases or explosive mixtures after ventilation on 1 March.

Again, mining progress through the broken granite was very slow. Heavy timbering driven along the back was necessary to hold up cavity rubble while making headway. Miners stopped driving the tunnel on 6 March to excavate an alcove for core drilling. Beginning 12 March, personnel were required to wear anticontamination coveralls, although general exposure rates at the tunnel face were only 3 mR/h with a maximum of 7 mR/h.

The first of two horizontal core drilling rigs was in place on 19 March and ready to drill from the alcove off the main tunnel 600 feet from the shaft. Mucking at the face was slow because drilling mud from the old postevent drill hole was encountered. It was necessary to pour concrete on the sides and floor to stabilize the mud area and proceed with the tunnel. The highest radiation level at the face was 6 mR/h, and no toxic gases or explosive mixtures were detected.

The first horizontal drill core pulled that was radioactive was from 134 feet in the "B" hole on 16 April, and it read 40 mR/h. The tunnel face was 8+18 (818 feet from shaft) and had passed over GZ (at 8+00). The exposure rate at the face was 8 mR/h, CO_2 was 2,000 ppm, $NO+NO_2$ was a trace, and no other gases or explosive mixtures were detected. The highest air temperature until that date, 98° F, with relative humidity of 92 percent, was recorded at 7+75 on 19 April. The highest core radiation level was 100 mR/h on a core from about 210 feet in "B" hole also on 19 April.

The maximum tunnel heading of 8+85 was reached on 30 April. The exposure rate at the face was 2 mR/h compared to 5 mR/h at 8+50. No toxic gases or explosive mixtures were detected either at the face or at the drilling alcove. Miners left the face and began restoring timber at 7+50.

On 30 April, most underground personnel not working on the face had headaches, and one became ill. These problems were attributed to high temperatures and humidity. An attempt was made to correct the problem by increasing ventilation. On 3 May, the highest tunnel temperature was 108° F with 100 percent relative humidity at 7+25. However, no personnel were working at this location.

A crosscut was constructed at 7+55 to obtain rock for analysis. On 8 May, the general exposure rate in the west crosscut drift was 15 mR/h, and the highest contact reading was 45 mR/h. Muck coming from this location read 15 mR/h and its temperature was 100° F. On 9 May in the east drift, the general exposure rate was 30 mR/h, and the highest contact reading was 60 mR/h. There was a trace of CO_2 throughout the main tunnel, and no other toxic gases or explosive mixtures.

The HARD HAT cavity mining and drilling operations were secured on 17 May 1963.

3.5 RESULTS AND CONCLUSIONS

Underground telemetry detector stations B6A and 4+65 did not respond after zero time due to line damage. Other readings for 15 February were not above background through the time telemetry was secured. After telemetry was resumed, station 0+40 had a maximum reading greater than 10 R/h until 2205 hours 16 February when the reading decreased to 8.9 R/h. Station 0+40 continued its decrease to less than 10 mR/h on 4 March. Station 0+35 indicated a maximum reading of 160 mR/h on 16 February, decreasing to less than 10 mR/h on 17 February.

Telemetry instruments located 100 feet north of SGZ, near sample pot number 1, 100 yards east of the shaft collar, at trailer No. 82, and at Stake L-67 indicated background radiation readings on 15-16 February. However, the unit near sample pot number 1 malfunctioned, and the unit 100 feet north of SGZ may have malfunctioned.

The aerial monitoring team first entered the area approximately 40 minutes after zero time on 15 February. No increase above background levels of radiation was detected in the downwind area. The aerial team again entered the area at 1050 hours on 16 February, and detected effluent measuring a maximum of 0.15 mR/h gamma above background in the area north of SGZ to a distance of eight miles. No effluent was detected off the NTS.

Fifty-three gamma film badge packets which had been placed on stakes in the area were collected to evaluate exposure to the gaseous effluent. Exposures were below the 30 mR threshold of film sensitivity.

Maximum readings during radiation surveys on the surface were 100 mR/h in the shaft collar area at 2155 hours on 15 February, and 10 R/h inside sample pot number 2 at 0630 hours on 16 February. The maximum reading during postevent drilling from the surface was 2,500 mR/h in contact with a core sample on 5 May, but the maximum personnel exposure rate was less than 5 mR/h near SGZ on 16 February.

Maximum measurements during shaft reentry were 0.5 mR/h on the test elevator and less than 1 mR/h on reentry personnel gloves and communication wire 22 February and 23 February, respectively. Maximum radiation readings during tunnel reentry were 5 mR/h in contact with the tunnel floor, and a personnel exposure rate of 0.15 mR/h in "A" drift on 5 June 1962.

Cavity mining and drilling operations encountered a maximum contact measurement of 100 mR/h on a core sample from "B" hole on 19 April 1963. The maximum personnel exposure rate was 30 mR/h in the east drift of the 7+55 crosscut on 9 May 1963.

Radsafe Area Access Registers were used and pocket dosimeters were issued for the potential radiation exposure period during postevent drilling from 17 February to 5 April 1962. Self-reading pocket dosimeter results on Access Registers for each individual entry are summarized below.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	155	75	0.9
DOD Participants	5	0	0

Radsafe Area Access Registers were used and pocket dosimeters issued from 14 February to 17 May 1963 during cavity mining and drilling operations. Self-reading pocket dosimeter results on Access Registers for each individual entry are summarized below.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	1,130	140	11
DOD Participants	14	140	23

A study of cumulative radiation exposures of all participants from 14 February to 17 May 1963 during the period of cavity mining and drilling operations indicated the following results from film badge records:

Maximum exposure, 230 mrem
Average exposure, 137 mrem
Minimum exposure, 35 mrem

CHAPTER 4

DANNY BOY EVENT

4.1 EVENT SUMMARY

The DANNY BOY event was a DOD nuclear detonation test with a yield of 0.43 kt conducted at 1015 hours PST on 5 March 1962. DANNY BOY was designed to be a cratering experiment on the Buckboard Mesa in Area 18 of the NTS. The device was emplaced in a 36-inch diameter shaft 110 feet below the surface elevation of 5,477 feet MSL in a basalt formation, which is a competent, fine-grained igneous rock. The resulting crater (Figure 4.1) was 62 feet deep and 214 feet in diameter. The purpose of DANNY BOY was to produce information about the cratering mechanism, ground shock, earth motion, propagation of energy, and other effects related to a cratering-type nuclear detonation in basalt. There were 12 DOD scientific projects conducted by government agencies and contractors to obtain information. The release of radioactivity was detected both onsite and offsite.

4.2 PREEVENT ACTIVITIES

4.2.1 Responsibilities

DANNY BOY was fielded by LRL for the DOD. A military officer of the CTO Engineering and Construction Division served on the staff of the LRL Test Director and coordinated all DOD requirements through the LRL Engineering and Construction Division. The major DOD operational contributions were providing aircraft for cloud sampling and cloud tracking, and aircraft and helicopters for photography, radiation monitoring, and radiation detector probe experiments. In addition, teams for monitoring

Figure 4.1 DANNY BOY Crater

and sampling the fallout area to five miles from SGZ were provided by the Army Chemical Corps Nuclear Defense Laboratory (NDL).

Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Field Command, DASA, and the AEC Albuquerque Operations Office. Sandia Corporation was responsible for emplacing and detonating microbarograph HE shots. EG&G was responsible for providing and installing timing and firing circuits. LRL had responsibility for device emplacement and arming the device.

4.2.2 Planning and Preparations

In addition to drilling the emplacement shaft, it was necessary to construct radial roads to 25,000 feet from SGZ. The event would not be conducted unless predicted fallout was in the sector where fallout stations were located. A circle road was constructed at 2,500 feet from SGZ and arc roads were constructed in the sector at 5,000, 10,000, 17,000, and 25,000 feet from SGZ (see Figures 4.5 through 4.7 on pages 4-24 through 4-26).

The "DANNY BOY Reentry Plan" described preevent preparations and postevent procedures used to conduct safe and efficient recovery operations in the test area. The "Test Manager's Special Instructions and Schedule of Events for DANNY BOY" was compiled and distributed to participating organizations.

Because the DANNY BOY event was expected to produce a radioactive effluent cloud, the DOD provided four Air Force B-57 aircraft for cloud sampling support. Air Force personnel established procedures for removing aircrews and sample filter papers from cloud sampling aircraft.

A. Radiological Safety Support

The "Detailed Safety Support Plan, DANNY BOY EVENT," was prepared by Radsafe and distributed to participating agencies. Radsafe personnel stocked the Quonset T-265 radsafe facility at Indian Springs AFB with film badges and anticontamination clothing and equipment in preparation for support of B-57 cloud sampling aircraft and other aircraft staging from ISAFB.

Test area maps with appropriate reference points were prepared. Reference stakes, fallout trays, air sampling equipment, and film dosimeter packets were positioned prior to the test event. Party monitors were briefed regarding reentry, sample recovery, manned stations, and security requirements.

Radsafe stationed a survey team at the Test Director's FCP 7.5 miles southeast of SGZ at one hour before detonation. This team was to provide emergency monitoring capability to the Test Director if needed. Additional Radsafe personnel established facilities at the FCP several days prior to the event. They manned a mobile decontamination facility, a telemetry readout trailer, and a check station trailer. The check station and decontamination trailers were to be moved into the test area after zero time to a location near and controlling access to radex areas.

Radsafe personnel were to perform surveys and to provide emergency support as directed; provide and issue anticontamination equipment, portable instruments, and self-reading pocket dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination as necessary. Personnel at manned stations were provided anticontamination clothing and equipment, and Radsafe monitors were assigned as required.

Anticontamination materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

High-volume Staplex air samplers equipped with MSA organic cartridges and 8 x 10-inch glass fiber prefilters were positioned at the following locations:

Area 12 Camp
Near I, J, K Tunnel Portals (in Area 12)
Area 15
Area 9 Radsafe Base Station
Station 700 Security Gate
Well 3
Area 400-401
CP-2 Building
Area 3 Radsafe Base Station

Film badges and fallout trays were placed on access road stakes in the test area and adjacent areas, but not in the area from SGZ to five miles covered by the Army Chemical Corps NDL teams with their own film badges and fallout stations.

B. Telemetry Support

Permanent telemetry units were in operation at the following NTS locations during DANNY BOY (see Figure 1.5):

1. G Tunnel (Area 12)

2. K Tunnel (Area 12)
3. Area 12 Cafeteria
4. Security Gate 700 (NE Corner NTS)
5. Area 9, 9-800 Bunker
6. BJY
7. Area 3, 3-300 Bunker

Test area Radsafe telemetry units were located as follows (see Figures 4.5 through 4.7):

1. North, 5° west, 10,000 feet from SGZ
2. North, 59° east, 13,000 feet from SGZ
3. Below Mesa on access road, 6,500 feet east of SGZ
4. On Mesa at rim, 2,500 feet east of SGZ
5. North, 55° west, 7,500 feet from SGZ

Test area LRL telemetry units all were located 2,500 feet from SGZ as follows:

1. North, 80° west
2. North, 55° west
3. North, 30° west
4. North, 5° west
5. North, 20° east
6. North, 45° east

Readout locations for telemetry units were at the FCP and Building CP-1. Measurements were relayed by telephone and net 3 radio.

C. Security Coverage

About four hours before planned zero time, security personnel began to muster all personnel entering or already in Area 18. Barricades and manned security stations were in place and access to the area was controlled. Muster badges were issued which were required to be returned upon exit as a means of accounting for personnel in the controlled area. A screening station was arranged approximately 100 yards east of the FCP to direct visitors to the observer area. The final ground and air security sweeps of all closed areas were accomplished from three hours prior to scheduled device detonation until one and one-half hours prior to scheduled device detonation. By this time the area was cleared of all personnel except those in the arming party or who had specific authorization to be there, temporarily or at manned stations.

D. Air Support

Elements of the AFSWC 4900th Air Base Group provided U-3A aircraft and crews to perform low altitude cloud tracking and C-47 aircraft and crews for radio relay and courier missions. Elements of the 1211th Test Squadron (Sampling) were attached to ISAFB for ten days for this nuclear event. Their primary mission was cloud sampling, which included conducting the sampling mission, removing the sample filters, and packaging and loading the samples onto courier aircraft. Personnel from this unit also assisted REECo Radsafe in implementing radiological safety procedures and decontaminating aircraft, crews, and equipment at ISAFB. The 55th Weather Reconnaissance Squadron supplied one WB-50 aircraft and crew to perform high-altitude cloud tracking.

Four USAF B-57's orbited near the area in readiness for cloud sampling at 15 minutes before detonation. The Air Force U-3A aircraft with PHS monitors aboard departed ISAFB for NTS and orbited near Area 18 until cleared by the Air Controller to fly over the event area and perform cloud tracking. U.S. Geological Survey (USGS) personnel performed preevent and postevent aerial monitoring using airborne scintillation detector logging equipment. A USAF helicopter with pilot, Radsafe monitor, and an LRL photographer orbited upwind from SGZ to perform documentary photography.

Two Marine Corps UH-43D helicopters, each manned by a pilot, co-pilot, and crewman, were at the FCP helicopter pad prepared to transport project personnel, place radiation dose rate recorders, and conduct radiation surveys with NDL monitors aboard.

4.2.3 Late Preevent Activities

Activities conducted on 4 March (D-1 day) included the following:

1. A Sandia representative assisted by four REECo personnel transported microbarograph HE and loaded it on three towers in the test area.
2. Two Sandia personnel checked out air blast gauges located 200, 265, 350, 470, 630, 840, 1,120, 3,100, and 8,500 feet from SGZ.
3. Four DOD personnel photographed the terrain within 1,000 feet of SGZ.
4. Ten three-man teams of NDL and LRL personnel completed installation of fallout stations and replaced background film badges installed three days earlier.
5. Four Armour Research Foundation (ARF) and four REECo personnel emplaced objects on the surface and one-foot deep within a 270-degree sector between 25-foot and 120-foot radii of SGZ.
6. One team of eight Waterways Experiment Station (WES) and LRL personnel conducted data recovery dry runs

at the trailer park one mile southeast of SGZ. A second team of four personnel observed the procedures.

7. A team of two EG&G personnel placed "Beer Mug" dosimeters (named for the shape of the metal containers) at 250-foot intervals from SGZ out to 1,250 feet on four radials.
8. Three WES and LRL personnel assisted by four REECo personnel spread tarpaulins within a 200-foot circle around SGZ.
9. Five two-man teams from EG&G began loading photo stations at 1000 hours.
10. A Test Manager's weather briefing was held at 1600 hours in the Conference Room of Building CP-1.
11. The final Area 18 dry run was conducted at 1800 hours.

4.3 EVENT-DAY ACTIVITIES

From midnight until three hours before scheduled detonation, five WES and LRL personnel performed final button up of instrumentation at the one-mile trailer park. From midnight until two hours before planned detonation, four DOD and Stanford Research Institute (SRI) personnel photographed the terrain within a 1,000-foot radius of SGZ.

From eight until seven hours before scheduled detonation, LRL and REECo personnel lowered the device cannister in the shaft, and stemming of the shaft began six hours before zero time. Two Sandia personnel armed the microbarograph charges at five hours before planned zero time.

From six hours to three hours before planned zero time, four ARF and four REECo personnel placed small objects on the surface within a 25-foot circle around SGZ and within a 120-foot radius in a 90-degree sector.

The USAF pilot and security guard sweeping Area 18 in an L-20 aircraft from three hours until one and one-half hours before planned detonation confirmed that no unauthorized traffic was in the test area or approaching over outlying rough terrain.

At two hours before planned detonation, three manned station parties entered the area. Two were Sandia two-man teams. The third and closest team was a seven-man DOD photography unit stationed 22,500 feet southwest of SGZ to perform still and motion picture photography of the event.

The final Test Manager's weather briefing was held at CP-1 at 0815 hours, two hours before planned detonation. The area was clear of all except manned station and arming party personnel by 0845 hours. After receiving permission from the Test Manager and Test Group Director at 0845 hours, the LRL and EG&G team armed the device and departed SGZ.

Thirty minutes before scheduled detonation, announcements were made and countdowns began on loudspeakers and radio nets 1, 2, 6, and 8. Fifteen minutes later, support aircraft departed ISAFB and the photography helicopter was orbiting upwind from SGZ. At 10 minutes before zero time, the siren on Building CP-1 was turned on for 30 seconds, and CP-1 red lights were turned on until after the detonation. A 2,400-pound HE microbarograph shot was fired at two minutes before zero time.

DANNY BOY zero time was 1015 hours PST on 5 March 1962.

The nuclear detonation produced a persistent cloud containing appreciable quantities of radioactivity associated with dust particles. The cloud grew rapidly to a width of about 3,000 feet and a height of about 1,000 feet above ground. After approximately three minutes, the continuing growth was controlled primarily by diffusion, the cloud height was 1,400 feet, and the cloud was moving rapidly downwind.

The microbarograph shot scheduled to be fired at three minutes after zero time detonated at zero time for an unknown reason. The zero plus five-minute shot fired on time.

4.3.1 Cloud Sampling and Tracking

After observing cloud formation for a few minutes, the four USAF B-57 cloud sampling aircraft began sampling. An LRL scientific controller in one of the aircraft evaluated cloud structure and determined cloud locations where samples would be collected. Samples were collected and aircraft departed by 1040 hours. Aircraft landed at ISAFB, aircrews left the aircraft, and cloud sample filter papers were removed by 1115 hours.

The U-3A aircraft entered the area at 1041 hours at which time a reading of 2 R/h was obtained at 8,000 feet MSL (SGZ elevation was 5,474 feet MSL). The aircraft then followed above the west edge of the cloud at 9,000 feet MSL on a 305 degree bearing for eight miles. At 1125 hours the cloud was centered eight miles southeast of Mellan, Nevada, a deserted town, where it topped at 8,000 feet MSL. From an altitude of 9,000 feet the peak reading was 250 mR/h. Cloud width was approximately five miles.

A snow storm was encountered above Highway 6, making further tracking impossible. At 1307 hours, the aircraft returned over SGZ at an altitude of 7,500 feet MSL where a reading of 4 R/h was measured. All readings were gross gamma as measured inside the aircraft and were not corrected for aircraft attenuation which probably was in the range of 30 to 50 percent.

The cloud first was detected by offsite PHS ground monitors at 1106 hours near Jackpot Reservoir, Nevada, 27.5 miles from SGZ on a bearing of 357 degrees. On moving into the cloud path, a peak of 400 mR/h was measured at 1118 hours 24.2 miles from SGZ at 348 degrees. Also at this distance, the cloud was detected over a width of 13 miles. On a second road crossing, a cloud pattern peak reading of 130 mR/h was measured at 1140 hours 41.5 miles from SGZ on a bearing of 344 degrees, which is 2 miles southwest of Mellan, Nevada. Seven minutes later, in Mellan, the reading was 4.0 mR/h.

Cloud arrival time at fallout station 1119 on old Highway 25 was 1137 hours. This station indicated a peak reading of 56 mR/h at 1149 hours. The level of activity dropped to 33 mR/h at 1151 hours. Then it fluctuated between 20 and 42 mR/h until dropping to 15 mR/h at 1208 hours. The remaining activity of 10 mR/h at 1210 hours appeared to be fallout deposited during cloud passage. Cloud width, as determined by offsite ground monitoring at this distance, was 21 miles, with a peak near the middle, about two miles east of Mellan.

At 1230 hours, the cloud was located on Highway 6 at a distance of 72 miles from SGZ and 8.7 miles west of Warm Springs on a bearing of 354 degrees. A peak reading of 3.2 mR/h was measured 17.7 miles west of Warm Springs on a bearing of 345 degrees from SGZ at 1246 hours. Ground monitoring indicated the cloud width was 22 miles crossing Highway 6. No activity was found along Highway 8-A or on Route 82 through Belmont, Nevada.

USGS aerial monitoring with scintillation detector logging equipment before the event and two days after detonation allowed normalization of the offsite fallout pattern to exposure rates at one hour after detonation. The resulting contours are shown in Figure 4.2.

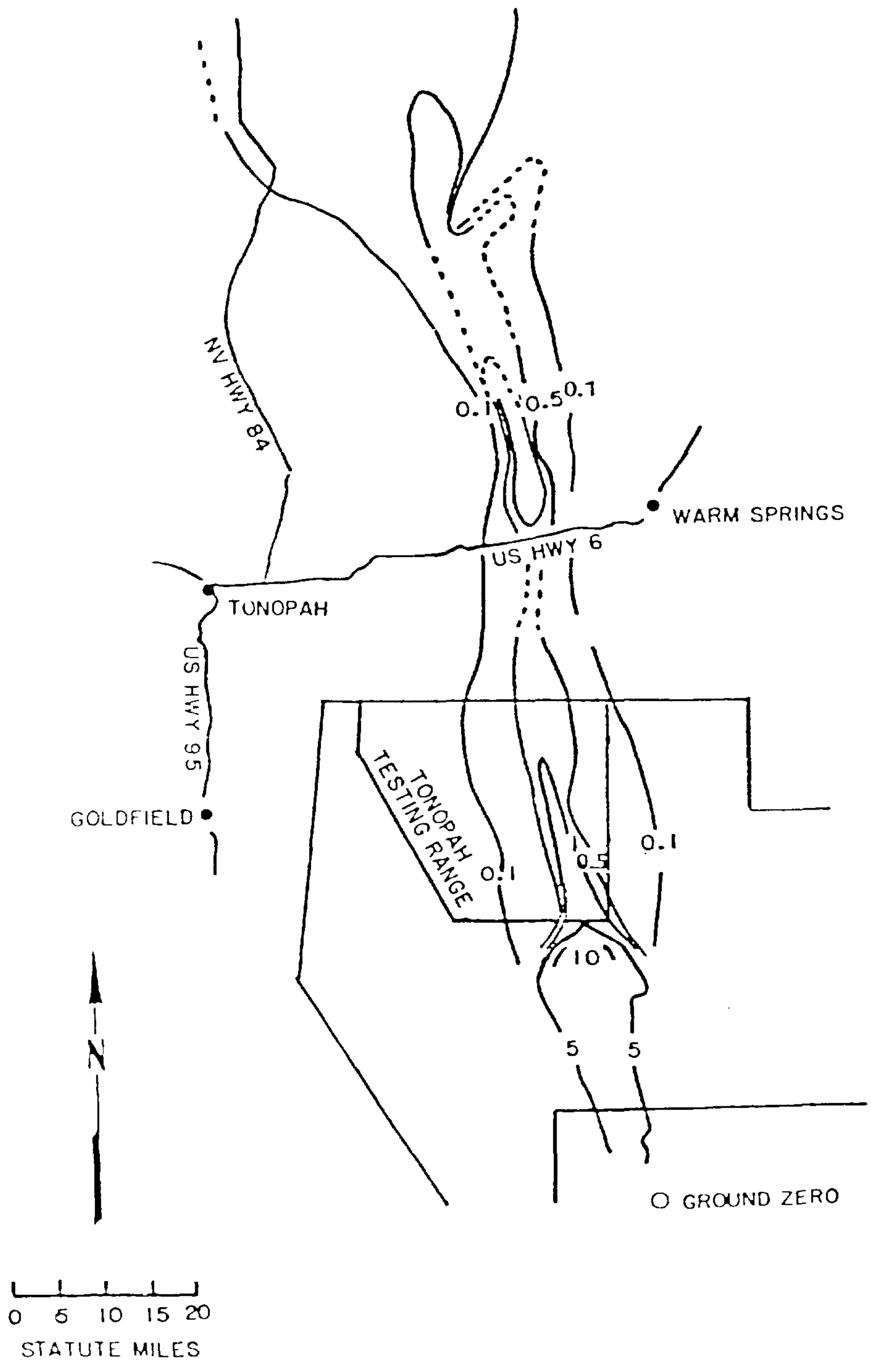

Figure 4.2 DANNY BOY Contours of Gamma Radiation in mR/h Normalized to H+1 Hour from USGS Aerial Survey Data

4.3.2 Test Area Monitoring

Radsafe telemetry units 2,500 and 6,500 feet east of SGZ indicated 500 mR/h one minute after detonation. One minute later, the 6,500-foot unit indicated background and the unit 2,500 feet east of SGZ continued to indicate 500 mR/h. At four minutes after zero time, the unit 10,000 feet north (downwind) of SGZ indicated 1,500 mR/h, but the unit 2,500 feet east of SGZ suffered mechanical failure.

The unit 10,000 feet north of SGZ indicated increasing gamma radiation intensities as the cloud rapidly passed over the location and fallout occurred. The maximum reading was 120 R/h at 1024 hours. Decreasing readings indicated cloud passage and fallout had occurred by 1034 hours, and resuspension of telemetry-detectable activity by high winds had ceased at 1125 hours. Winds on the surface at zero time had been 12 knots from 168°, increasing to 27 knots from 190° at 3,500 feet above the surface.

Table 4.1 shows Radsafe telemetry measurements in the test area. Permanent Radsafe units at other NTS locations indicated only background after DANNY BOY. Records of LRL telemetry measurements are not available. However, these measurements were incorporated with Radsafe telemetry in normalizing NDL ground monitoring data to exposure rate contours at one hour after detonation, as discussed later in this section.

Marine Corps helicopters provided support for test area monitoring, transport of monitoring and project personnel, and placement of radiation detection equipment for NDL, LRL, and WES personnel after the event. Exact times for these activities are not available, but times listed in the Test Manager's "Schedule of Events" and the "Reentry Schedule" are used below.

About 30 minutes after zero time, the two Marine Corps UH-

TABLE 4.1

DANNY BOY EVENT

RADSAFE TELEMETRY MEASUREMENTS IN TEST AREA
(Gamma Radiation in R/h)

TIME (PST)	N 5° W 10,000'	N 59° E 13,000'	BELOW MESA 6,500' EAST	ON MESA 2,500' EAST	N 55° W 7,500'
1016	Bkg	Bkg	0.50	0.50	Bkg
1017	Bkg	Bkg	Bkg	0.50	Bkg
1019	1.50	Bkg	Bkg	Mechanical	Bkg
1020	5.00	Bkg	Bkg	failure of	Bkg
1021	15.00	Bkg	Bkg	detector	Bkg
1022	25.00	Bkg	Bkg		0.50
1023	65.00	<0.50	Bkg		Bkg
1023	90.00	Bkg	Bkg		Bkg
1024	120.00	Bkg	Bkg		Bkg
1024	52.00	Bkg	Bkg		Bkg
1025	35.00	Bkg	Bkg		Bkg
1025	20.00	Bkg	Bkg		Bkg
1026	14.00	Bkg	Bkg		Bkg
1027	12.50	Bkg	Bkg		Bkg
1028	10.00	Bkg	Bkg		Bkg
1029	5.00	Bkg	Bkg		Bkg
1030	4.50	Bkg	Bkg		Bkg
1031	4.00	Bkg	Bkg		Bkg
1032	3.75	Bkg	Bkg		Bkg
1033	3.00	Bkg	Bkg		Bkg
1034	3.00	Bkg	Bkg		Bkg
1035	2.75	Bkg	Bkg		Bkg
1036	2.50	Bkg	Bkg		Bkg
1037	2.50	Bkg	Bkg		Bkg
1038	2.30	Bkg	Bkg		Bkg
1040	2.20	Bkg	Bkg		Bkg
1041	2.10	Bkg	Bkg		Bkg
1042	2.00	Bkg	Bkg		Bkg
1043	2.00	Bkg	Bkg		Bkg
1045	1.80	Bkg	Bkg		Bkg
1047	1.60	Bkg	Bkg		Bkg
1050	1.40	Bkg	Bkg		Bkg
1055	1.20	Bkg	Bkg		Bkg
1100	0.90	Bkg	Bkg		Bkg
1105	0.75	Bkg	Bkg		Bkg
1110*	1.50	Bkg	Bkg		Bkg
1111	1.00	Bkg	Bkg		Bkg
1112	1.00	Bkg	Bkg		Bkg
1113	0.70	Bkg	Bkg		Bkg
1114	1.00	Bkg	Bkg		Bkg
1115	1.30	Bkg	Bkg		Bkg

*Increases in measurements attributed to high winds disturbing surface activity.

TABLE 4.1 (Concluded)

TIME (PST)	N 5° W 10,000'	N 59° E 13,000'	BELOW MESA 6,500' EAST	ON MESA 2,500' EAST	N 55° W 7,500'
1116	1.00	Bkg	Bkg		Bkg
1117	0.80	Bkg	Bkg		Bkg
1118	1.50	Bkg	Bkg		Bkg
1119	0.60	Bkg	Bkg		Bkg
1120	0.50	Bkg	Bkg		Bkg
1122	0.70	Bkg	Bkg		Bkg
1125	<0.50	Bkg	Bkg		Bkg
1127	<0.50	Bkg	Bkg		Bkg
1130	<0.50	Bkg	Bkg		Bkg
1135	<0.50	Bkg	Bkg		Bkg
1140	0.50	Bkg	Bkg		Bkg
1150	<0.50	Bkg	Bkg		Bkg
1200	<0.50	Bkg	Bkg		Bkg
1212	<0.50	Bkg	Bkg		Bkg
1220	<0.50	Bkg	Bkg		Bkg
1230	<0.50	Bkg	Bkg		Bkg
1245	<0.50	Bkg	Bkg		Bkg

43D helicopters and crews transporting NDL monitoring teams left the FCP pad and monitored exposure rates at the south Buckboard Mesa pad, one-mile trailer park, and along the 5,000-foot and 10,000-foot arc roads. One NDL monitoring team was transported to the south pad and one to the intersection of 25,000-foot arc road with west radial road where prepositioned vehicles were available. The south pad monitoring team proceeded to the one-mile trailer park with instructions not to proceed beyond 1 R/h.

Two dose rate recorders were lowered by helicopter, one in the crater and one on the lip of the crater. This helicopter then performed aerial surveys of the radiation area using a probe lowered near the ground to determine exposure rates in areas not accessible to ground surveys teams. The second Marine Corps helicopter orbited outside the radiation area during placement of recorders to perform rescue service if necessary.

About 90 minutes after zero time, the second helicopter commenced shuttling project personnel to the south Mesa pad for data recovery. Also at this time, additional NDL monitoring teams approached the Mesa by vehicle from the FCP, and a total of 10 two-man NDL teams began ground radiation surveys of the test area within five miles of SGZ.

Because the teams encountered difficulty traversing rough terrain and their instructions limited radiation exposure rates they could enter, much of the close-in exposure rate contour pattern was not surveyed on event day. Subsequent NDL survey data combined with LRL and Radsafe telemetry data allowed normalizing the close-in exposure rate contours to one hour after zero time. These contours are shown in Figure 4.3. The NDL teams also placed three exposure rate recording units in the downwind area where exposure rates were between 1 and 5 R/h.

After completion of the first ground surveys about two hours

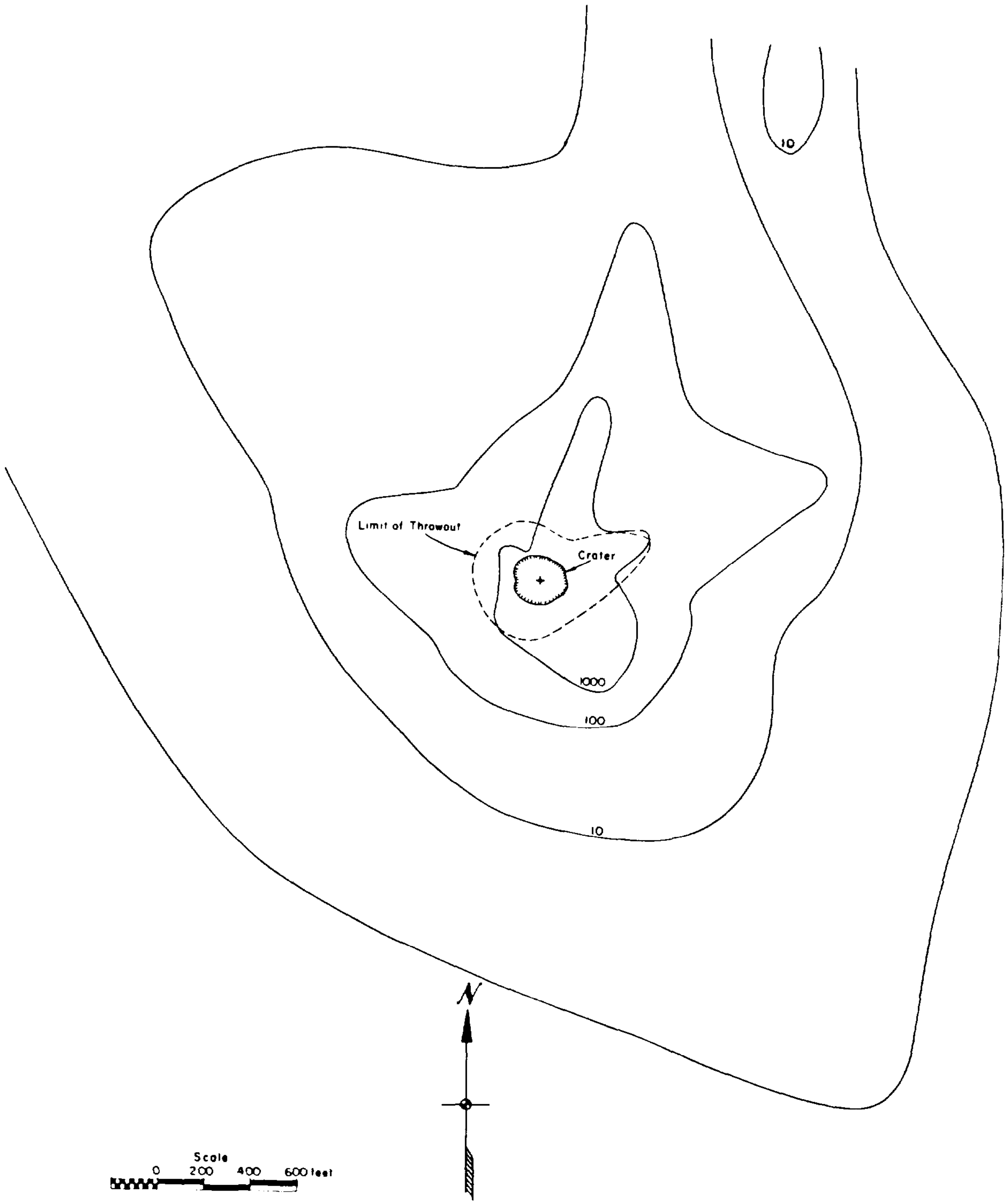

Figure 4.3 DANNY BOY Close-in Exposure Rate Contours in R/h Normalized to H+1 Hour

after zero time, six teams with one NDL and one LRL monitor each entered the area to perform resurveys, recover film badges, and collect fallout trays. Resurveys continued until dusk.

An EG&G aerial monitoring team performed a radiation survey from five until seven hours after detonation time in the intermediate area from less than five to about 24 miles from SGZ. These measurements were integrated with the NDL close-in data and the USGS aerial monitoring results to normalize exposure rate contours at one hour after detonation as shown in Figure 4.4.

4.3.3 Other Project Activities

Recovery operations began about 90 minutes after zero time. Microbarograph firing sites were checked for unburned HE, and equipment was removed by Sandia and REECo personnel. Air blast gauges from 200 feet to 8,500 feet from SGZ were recovered by Sandia personnel.

Three SRI and LRL personnel photographed the terrain within 1,000 feet of SGZ by helicopter while EG&G and LRL personnel recovered films from photography stations on the surface. Four SRI personnel accompanied by a Radsafe monitor performed ground-level photography within 1,000 feet of SGZ.

Four LRL personnel recovered data from the one-mile trailer park, two USC&GS personnel recovered data from seismic stations, and two EG&G personnel recovered "Beer Mug" dosimeters on four radials to within 250 feet of SGZ. Two WES personnel proceeded via helicopter to recover data from the WES trailer.

4.3.4 Radsafe Activities

The 45 aircrew and ground crew personnel who had been provided anticontamination clothing and equipment, self-reading

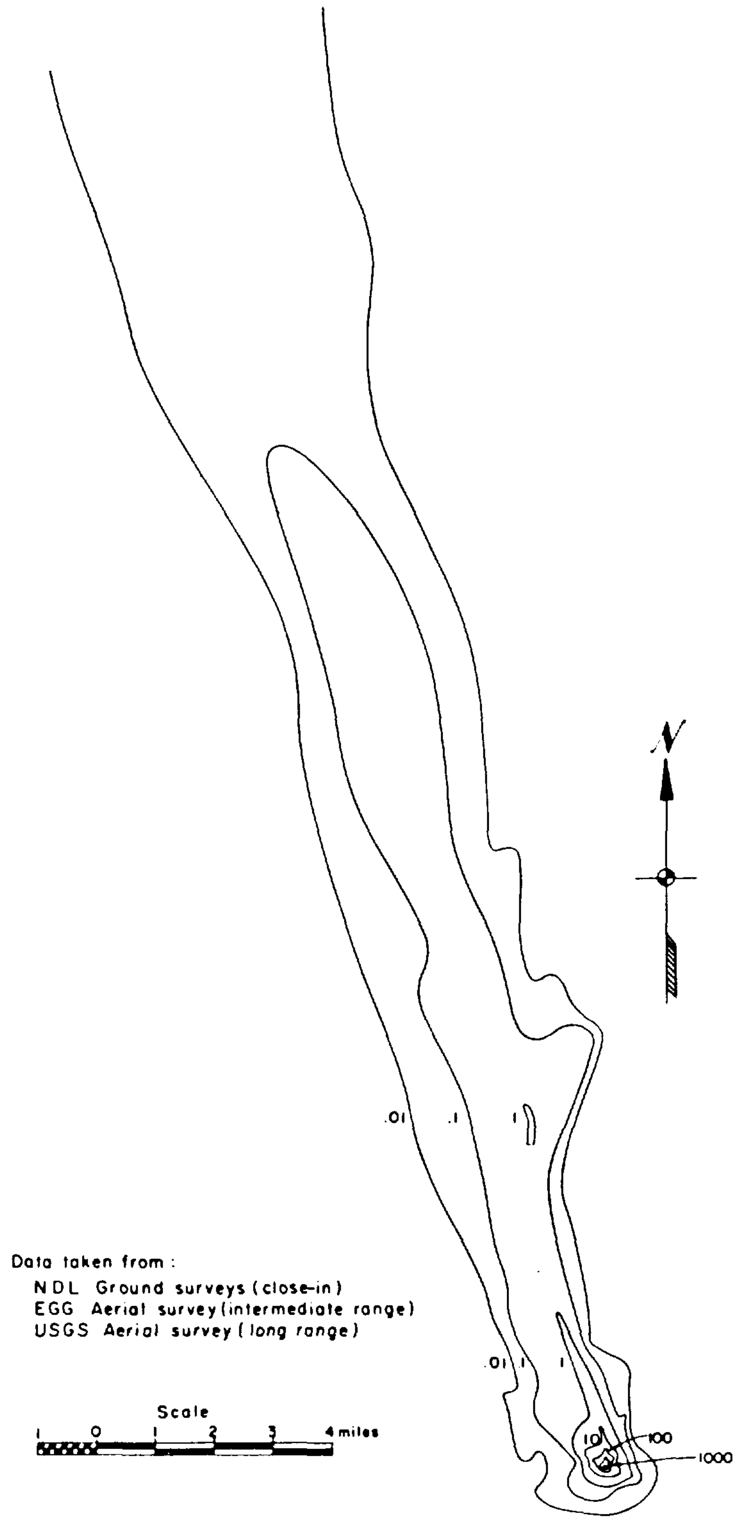

Figure 4.4 DANNY BOY Intermediate Range Exposure Rate Contours in R/h Normalized to H+1 Hour

pocket dosimeters, and film badges were processed through the ISAFB radsafe facilities after sampling aircraft had returned and samples had been recovered. Pocket dosimeters and film badges were collected, personnel were monitored before and after anticontamination clothing was removed, and personnel were decontaminated as necessary before they dressed in their own clothing. Maximum gamma readings of 20 mR/h were detected on anticontamination gloves.

Film badges issued, collected, and processed included 20 experimental film badges which had been positioned in the four cloud-sampling aircraft, eight film badges worn by sampling aircraft pilots, 26 worn by sample recovery and maintenance crews, and eight worn by helicopter pilots. Maximum gamma measurements on the sampling aircraft were several R/h before removal of sample filters and 1.5 R/h after removal.

Personnel entering DANNY BOY radex areas were issued anticontamination clothing and equipment before entry, were monitored and decontaminated as necessary upon exit, and had their film badges exchanged. Security personnel controlled access to the test area according to the Test Manager's "Schedule of Events" and release of parties by the LRL Test Director.

At 1243 hours, the Radsafe check station and decontamination trailers were moved from the FCP to a location 2.9 miles southeast of SGZ on the access road to Area 18. All film badges exchanged on event day were processed by midnight, and a special exposure report was prepared for the next day. Use of Radsafe Area Access Registers, with pocket dosimeter readings noted upon exit, was not implemented until control of the test area was delegated to Radsafe the day after DANNY BOY.

The special report was used in place of Access Register pocket dosimeter readings in alerting Radsafe to personnel who were approaching accumulated exposure amounts of 5,000 mrem per year or 3,000 mrem per calendar quarter, the AEC guidelines. Individuals and their organizational supervisors were notified when personnel had accumulated 4,500 mrem per year or 2,500 mrem per calendar quarter.

4.4 POSTEVENT AND CONTINUING ACTIVITIES

Radsafe established radex area controls in Area 18 the morning after detonation of DANNY BOY. Surveys of the test area were performed to establish the 10, 100, and 1,000 mR/h exposure rate contour lines. This D+1 survey was repeated on D+2, 3, 4, 6, 7, 8, 10, 17, and 24. Figures 4.5, 4.6, and 4.7 show the D+1, 2, and 3 surveys, respectively. In addition to contracting as radioactivity decayed, the 10 mR/h line shifted with water movement on the surface. Detailed surveys in exposure rates up to 5 R/h were made near the crater and on the crater lip. Monitoring data were transmitted to NDL personnel for correlation with their monitoring results.

Test areas and all contaminated or radioactive materials were marked to indicate radiation levels. Personnel entering radiation areas or working with contaminated material were briefed concerning potential exposures and safety precautions, and were provided with anticontamination clothing, equipment, and materials.

After use, anticontamination clothing and equipment were laundered and returned to stock for subsequent reissue. Items which could not be decontaminated to permissible levels were buried at the designated disposal site.

On D+1, radiation measurements on cloud sampling aircraft at ISAFB were down to 20 mR/h generally and 40 mR/h maximum. Air-

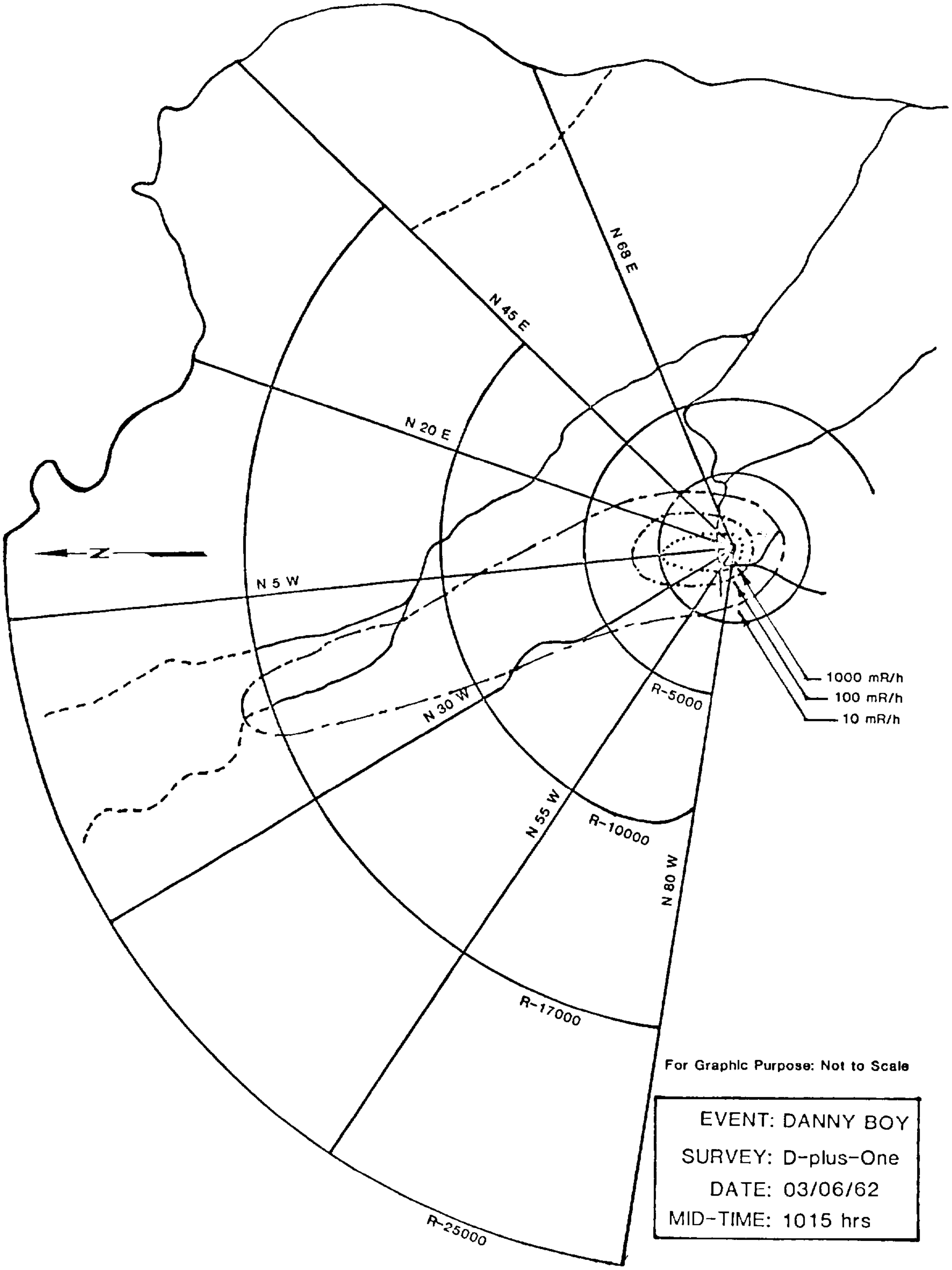

Figure 4.5 DANNY BOY D-plus-One

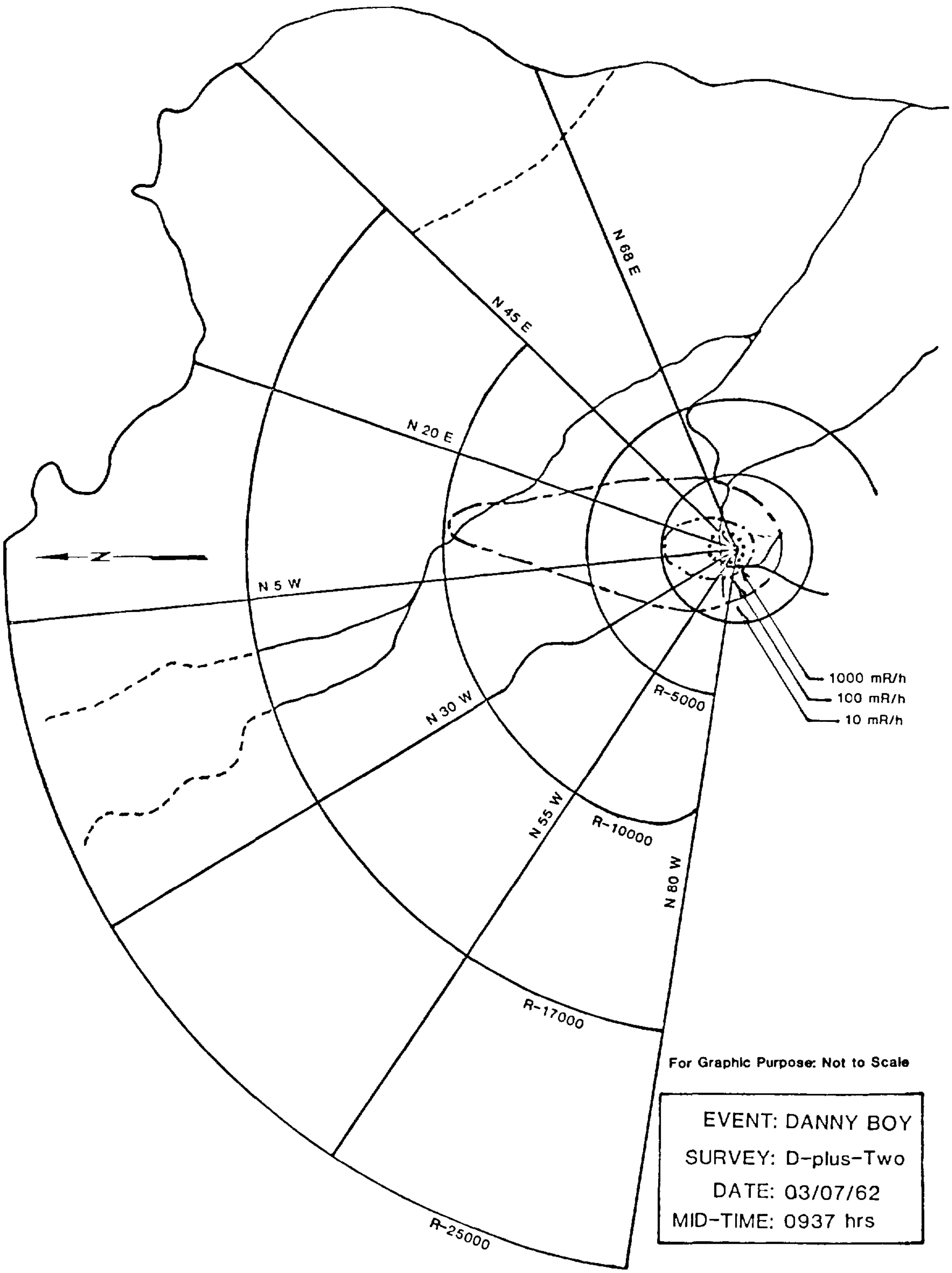

Figure 4.6 DANNY BOY D-plus-Two

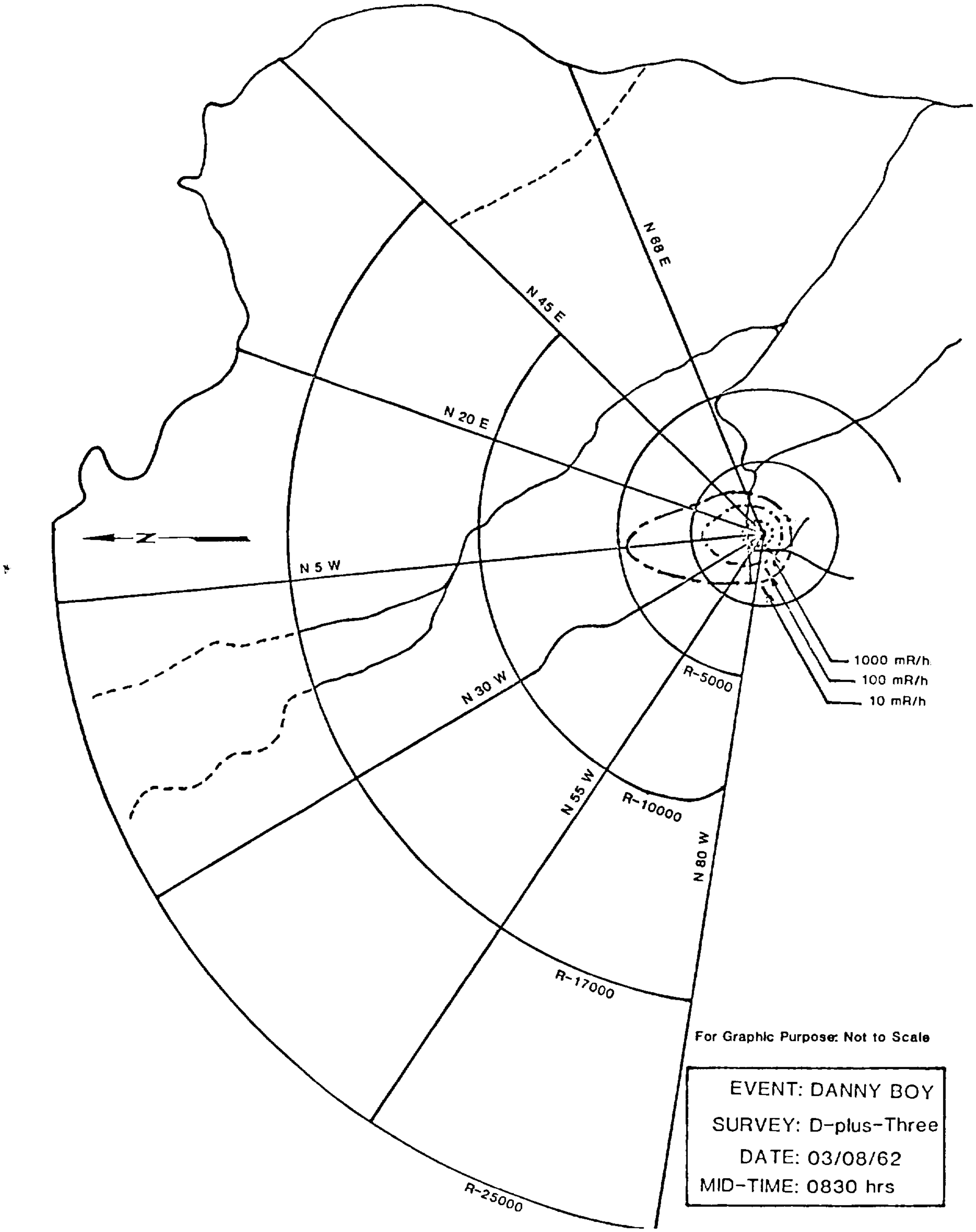

Figure 4.7 DANNY BOY D-plus-Three

craft decontamination was not required because radioactivity soon would decay below Air Force limits of 20 mR/h for fresh fission products.

4.4.1 Continued Recovery Operations

Radsafe supported various groups and agencies in the recovery of samples and equipment from the test area. Support consisted of sample monitoring, personnel monitoring, contamination control, and decontamination.

Ten two-man NDL monitoring teams reentered the area the morning of D+1 and resurveyed all stations which had exposure rates below 5 R/h. They also recovered fallout collectors not recovered on D-day, moved exposure rate recorders to higher radiation intensity locations, and recovered film badges not recovered on D-day. The same actions were repeated that afternoon after further decay of radioactivity. Aerial surveys with Marine Corps helicopters of areas not accessible to ground monitoring vehicles also were repeated beginning at 0700 hours.

A party of WES and LRL personnel, REECo laborers, and a Radsafe monitor performed data collection from tarpaulins outside the 100 mR/h exposure rate contour.

Radsafe had positioned an array of adhesive-surfaced sample collectors and 94 standard NTS film packets at quarter-mile intervals along the Area 18 access road to Buckboard Mesa, and on access roads to adjacent areas. Collectors and film badges were positioned 22 February, picked up 28 March, and processed 29 March. Fallout collector data were negative because collectors were not in the pattern. However, film badge data showed positive integrated exposures for several stations east to southeast of SGZ on the Mesa. The maximum exposure was 5 R at a station 5,000 feet due east of SGZ.

Twenty-four-hour monitoring surveillance was required for several days after the event. Radsafe monitors accompanied personnel entering the area and provided routine radiological safety support and information on radiation levels.

Monitoring surveillance of the test area continued for several weeks during daylight hours. A perimeter fence was erected around the crater area to facilitate area control.

4.4.2 Postevent Drilling

Postevent drilling for core samples was performed during May 1962 from outside the crater lip area. On 22 May 1962, the helicopter crash discussed in the next chapter occurred in the crater. Subsequently, work was done to remove the helicopter wreckage to determine the accident cause. On the southwest side of the crater, crater-lip rock was removed and a road 200 feet long and 20 feet wide was constructed to the edge of the crater. The exposed crater-lip rubble was more than 20 feet high near the sides of the road. The wreckage was winched up to this road for removal.

Core drilling outside the crater lip continued intermittently into 1963. In April and May 1963, WES personnel utilized the helicopter removal road to drill near the crater rim. A hole slanted toward GZ was drilled in the trench 50 feet from the crater edge with a truck-mounted core drill.

Maximum personnel exposure rates during this drilling were 10 mR/h at the side of the trench, 7 mR/h at the crater rim, and 5 mR/h at the core drill. The maximum contact reading with a core sample was 50 mR/h on a piece of fused glass. This drilling was completed in early May, and several more coring holes were drilled at distances up to 450 feet from the crater lip. The last hole was drilled from 7 August to 16 August 1963 210 feet west of the crater. All cores taken to the maximum depth of 141 feet measured background, and the personnel exposure rate at this location was about 1 mR/h.

4.5 RESULTS AND CONCLUSIONS

Telemetry units in operation during DANNY BOY did not indicate radiation above background except in the test area. The four units near the fallout pattern measured maximum levels of 500 mR/h. The unit in the pattern and 10,000 feet north of SGZ measured a maximum of 120 R/h nine minutes after detonation, which decreased to less than 500 mR/h by 135 minutes after detonation. The maximum integrated exposure determined with Radsafe film badges on roads near the pattern was 5 R at 5,000 feet due east of SGZ.

Personnel film badges were exchanged after the event when personnel exited the radex area. All film badges exchanged at Area 18 on 5 March were processed by 2400 hours that night, and a computer report was prepared. Exposures for Area 18 film badges processed 5 March are summarized as follows:

	No. of Positive Exposures	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	81	1,780	133
DOD Participants	47	1,780	161

Maximum exposures indicated by the 20 experimental and 42 personnel film badges turned in at ISAFB were as follows:

Experimental	-	500 mR
Sampling pilots	-	295 mR
Ground crew	-	30 mR
Helicopter pilots	-	1,700 mR

Personnel exposures received on individual entries to DANNY BOY radex areas from 6 March 1962 through 13 March 1962 are summarized below. Average exposures are from self-reading pocket dosimeters as recorded on Area Access Registers. Maximum exposures are from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	210	695	47
DOD Participants	164	580	40

As was expected, the DANNY BOY event resulted in high levels of airborne radioactivity and fallout close in, but by the time the cloud had traveled about 35 miles, both had decreased to a small fraction of the levels detected at 10 miles.

The PHS offsite radiological safety organization determined that no harmful exposure of the offsite population occurred after the DANNY BOY event.

CHAPTER 5

MARSHMALLOW EVENT

5.1 EVENT SUMMARY

The MARSHMALLOW event was a DOD underground detonation with a yield less than 20 kt conducted at 1000 hours Pacific Daylight Time (PDT) on 28 June 1962 at tunnel site U16a (Figure 5.1) in Area 16 of the NTS. The device was emplaced 2,130 feet from the tunnel portal with 1,000 feet of overburden. The MARSHMALLOW event was a weapons effects test. Effects of a nuclear detonation environment on equipment and materials at a simulated high altitude were studied. High altitude simulation was accomplished by establishing a vacuum in a large diameter LOS pipe more than 800 feet long. Desired information was obtained through 27 DOD scientific projects conducted by government agencies and contractors. Radioactive effluent released by this detonation was detected onsite only.

5.2 PREEVENT ACTIVITIES

5.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all MARSHMALLOW project activities in Area 16. This responsibility was in effect from the time the device was moved into the area until completion of recovery operations. Responsibilites of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Field Command, DASA, and the AEC Albuquerque Operations Office. LRL provided the device, EG&G provided firing circuits and timing signals, and SC was responsible for stemming and de-

Figure 5.1 Airview of MARSHMALLOW Portal Area

vice arming. Experiments were fielded for the DOD by EG&G, Lockheed Missile and Space Company (LMSC), SRI, Allied Research, American Science and Engineering, USC&GS, AFSWC, and FCDASA. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

5.2.2 Planning and Preparations

Work necessary to conduct the MARSHMALLOW event and scientific projects included excavation of tunnels totalling 3,005 feet in length, construction of alcoves and shield walls, installation of coaxial cable and mechanical systems, and fabrication of the vacuum system. Figure 5.2 shows plan and section views of the MARSHMALLOW underground complex. Figure 5.3 shows portal area facilities and the trailer park, which compares with Figure 5.1 at a different orientation.

Above ground recovery of data was necessary as soon as possible after the event due to radiation sensitivity of the records. Underground recovery of data was of secondary importance, but it was desirable to accomplish this as quickly as practical.

The "MARSHMALLOW Reentry Plan" described preevent preparations and postevent procedures used to conduct a safe and economical reentry within the desired time frame. Stemming design incorporated necessary provisions to maximize safety of reentry. A 14-inch diameter vertical vent hole to the surface was to provide pressure relief to protect the blast door and to provide ventilation exhaust for early reentry.

Because the 'Y' was a large unsupported span and otherwise would be especially vulnerable to collapse, a sand plug was installed at that point to provide support. A six-foot diameter pipe was installed through the plug into the LOS tunnel to provide access during reentry. Sandbags were to be used to plug the

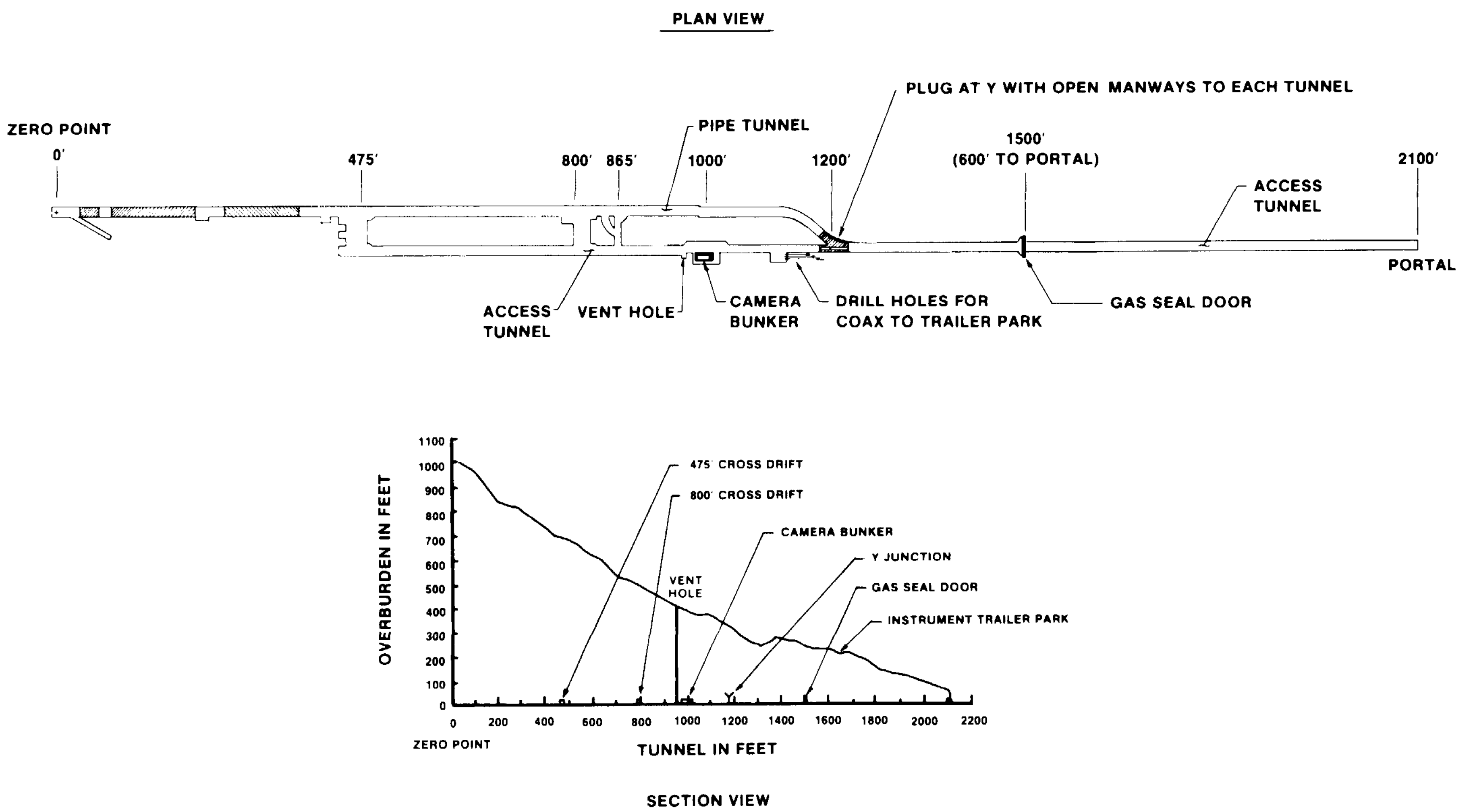

Figure 5.2 Plan and Section Views, MARSHMALLOW Event

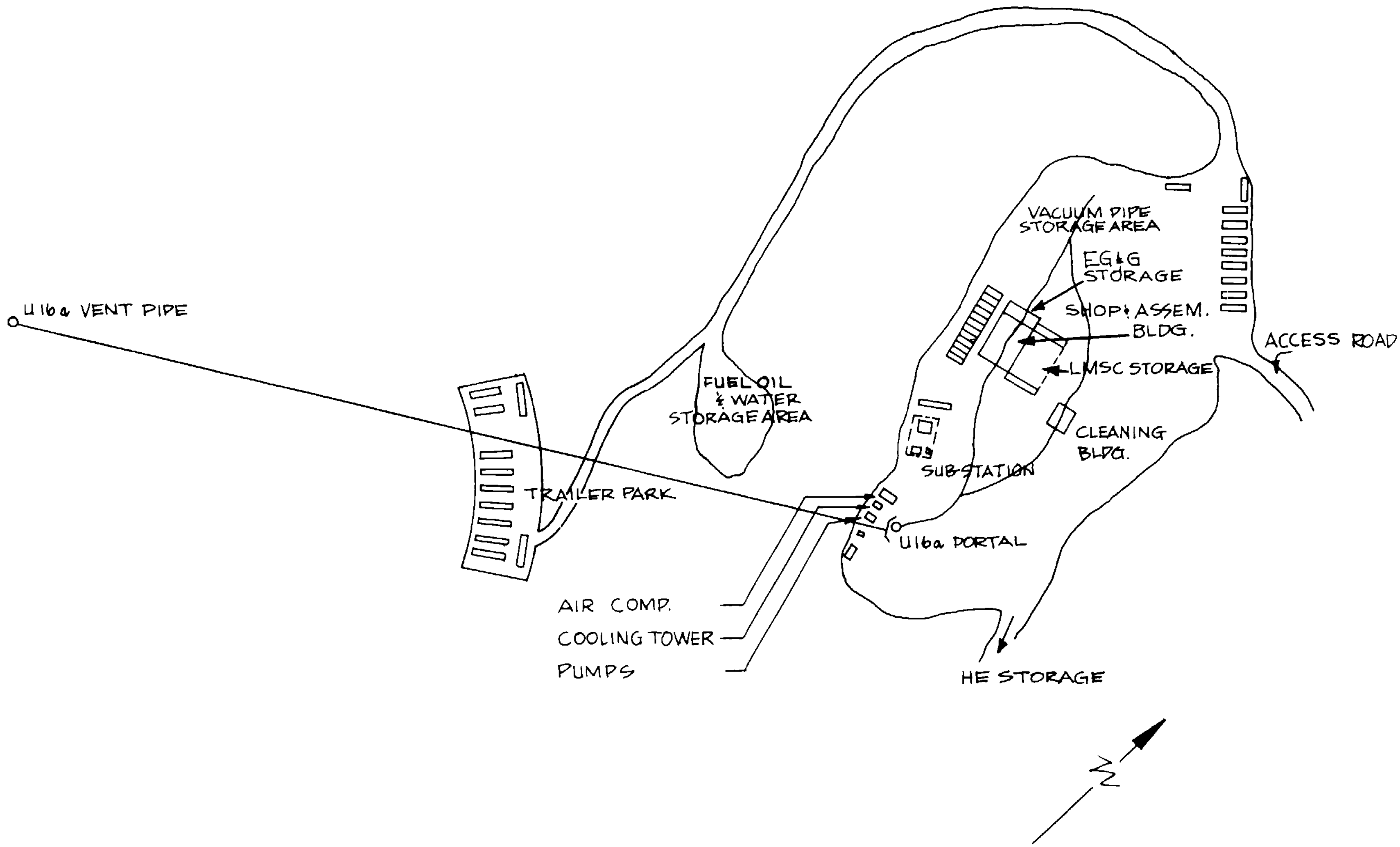

Figure 5.3 U16a Portal Area - MARSHMALLOW Event

reentry pipe temporarily for the detonation.

Air sampling pipes were installed through the blast door and into the EG&G camera bunker to determine conditions forward of these points during reentry. Lead plates were to be dropped over the camera ports in the camera bunker after zero time to shield film from transient radiation in the tunnel. A block and tackle were installed on the camera bunker door to aid in removal should the door be jammed.

Spare blowers for vent lines and the vent hole were available in case those installed before the event were damaged.

Instructions and equipment requirements established in the reentry plan included the following teams:

1. Reentry Control Group and Technical Advisors
2. Surface Radiation Monitoring and Aerial Survey
3. Trailer Surface Film Recovery
4. Tunnel Reentry Party
5. Tunnel Work Party
6. Rescue Party
7. Tunnel Film Recovery
8. HE Disposal Group
9. Medical Support Team

A. Radiological Safety Support

Detailed procedures for initial reentry were submitted to participating agencies prior to the test event. Test area maps with appropriate reference points were prepared. Reference stakes, fallout trays, radiation decay recorders, air sampling equipment, film dosimeter packets, and other dosimetric devices were positioned in the test area. Reentry routes into the test area were established during "dry runs." Party monitors were briefed regarding manned stations, reentry, sample recovery, and security station requirements.

All personnel at manned stations were provided with appropriate anticontamination clothing and equipment, and Radsafe monitors were in attendance. Radsafe provided monitoring teams and supervisory personnel for aerial surveys by helicopter, initial surface radiation surveys, and tunnel reentry parties.

Radsafe personnel were standing by at the FCP prior to detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment, portable instruments and dosimeters; operate area control check stations; and perform personnel, equipment and vehicle decontamination as required.

Anticontamination materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

B. Telemetry Support

RAMS units were installed and calibrated at the following underground and surface locations for MARSHMALLOW:

Underground Locations:

1. Outside gas seal door
2. Inside gas seal door
3. Outside Y (1,230 feet from device)

4. Camera Bunker
5. Crossdrift 8+65 (865 feet from device)
6. Crossdrift 8+00 (800 feet from device)

Surface Locations:

1. Intersection of main access and FCP roads
2. Main road at portal pad
3. Tunnel Portal
4. One-half mile from trailer park
5. One-quarter mile from trailer park
6. Transformer station
7. Outside trailer park - north
8. Outside trailer park - south
9. Inside trailer park - south
10. Inside trailer park - north
11. Vent line, southeast
12. Vent line, northwest
13. Three miles south of portal

Readout was at the Test Director's FCP. All readings were to be reported via net 3 radio.

C. <u>Security Coverage</u>

At 1800 hours on 27 June 1962, muster and control stations were established as follows:

1. main control and muster station on the main access road into Area 16 (5,000 feet east of the portal);
2. manned control station on the Pole Line Road in Area 16, two miles east of GZ;
3. manned control station on the junction of roads running north, south, east, and west, 5,000 feet south of the Area 16 border; and

4. manned control station west of GZ, approximately 2,500 feet west of the Area 16 border on access road to the drill rig area above U16a portal.

D. Air Support

An Air Force H-21 helicopter with a pilot, crew chief, Radsafe health physicist, and Radsafe electronics specialist were to monitor the portal and scientific trailer areas immediately after the detonation to determine if any release of radioactivity might damage data recording films before ground recovery could be accomplished. If such damage could occur, the helicopter was to pick up recovery personnel and land on a pad constructed on the trailers, thus allowing personnel to retrieve trailer park films before damage could occur.

In preparation for monitoring ground radiation levels, radiation detection instruments were calibrated over the DANNY BOY crater on 22 May 1962. Engine problems caused the H-21 to collide with the crater lip and crash upside-down as shown in Figure 5.4. The pilot, crew chief, health physicist, and electronics specialist all were assigned 115 mR external exposure on the basis of the health physicist's film badge, as the other film badges were lost in the crash. Internal exposures occurred, but were not assigned as only qualitative analysis data were available during medical treatment of personnel injuries, which took precedence.

After the Air Force H-21 crashed, a Marine Corps UH-43D helicopter was assigned to this monitoring and possible recovery operation.

An aerial survey of any radioactive cloud released was

Figure 5.4 Helicopter Crash in DANNY BOY Crater

to be conducted by a team of two PHS personnel in an Air Force U-3A aircraft, manned by an Air Force pilot and co-pilot. Radiation detection equipment carried included a Precision Model 111 scintillator with an added transistorized amplifier feeding an Esterline-Angus strip chart recorder, an EG&G aerial monitor, a Beckman MX-5 detection instrument and an AN/PDR-39 survey instrument.

A DOD party in an Air Force H-21 helicopter was to orbit upwind from GZ from 15 minutes before device detonation to 45 minutes afterward providing photography coverage.

An Air Force L-20 aircraft and pilot with a security officer were to perform a security sweep from two hours until 30 minutes before planned device detonation.

5.2.3 Late Preevent Activities

DOD and Allied Research personnel measured voltage differences between six electrodes placed in a line at 250-foot intervals on the surface. LMSC personnel calibrated instrumentation at two recording trailers and conducted dry runs with their equipment, both at the trailers and at instrument alcoves in the tunnel. FCDASA personnel supervised readiness and final button up of the tunnel experiment area.

SRI and EG&G personnel loaded film in cameras located in photography stations in the tunnel and on the surface. SRI personnel performed final checkout of electronic equipment. EG&G personnel monitored pumps and the overall vacuum system. LMSC and Special Weapons Center (SWC) personnel installed detonators for conventional explosives systems in the tunnel.

A Test Manager's weather briefing was held at 1600 hours on 27 June. The decision was made to proceed with preparations for the test, and security muster and control stations were established at 1800 hours.

5.3 EVENT-DAY ACTIVITIES

On D-day, SWC and LMSC personnel completed installation of detonators and armed the camera and closure systems. DOD and Allied Research personnel made additional voltage measurements at surface electrodes. EG&G personnel made final alignment checks, and loaded cameras and oscilloscopes.

All personnel were clear of the tunnel by six hours before zero time. Five hours before scheduled device detonation, the arming party departed the control trailer for U16a. For the next three hours, the arming party performed final arming in the tunnel, then returned to the control point.

Three hours prior to planned detonation, the main control and muster station was moved to a position near the Forward Control Point and observer area, approximately two miles east of U16a portal. A manned control station was established 12,500 feet north of the portal, just south of the Area 16 Camp. A manned control station was established on the Tippipah Springs Road on the west border of Area 16. Initial recovery parties were staged near the observer area on the Pole Line Road, which ran west toward the tunnel portal.

The final weather briefing for the Test Manager and Advisory Panel was conducted at 0700 hours, three hours before zero time. The arming party requested and received permission from the Test Group Director to arm the device at this time. After three hours prior to scheduled device detonation, the Pole Line Road was the only road open to Area 16. All personnel were clear of the controlled area at this time except the arming party and others who were authorized.

From two hours prior to scheduled detonation until 30 minutes prior to planned detonation the L-20 aircraft made a final security sweep of the closed portion of Area 16 and the surrounding rough terrain to assure that no unauthorized personnel were approaching the area.

The U-3A cloud monitoring aircraft departed ISAFB at 40 minutes before zero time. The H-21 photography helicopter was orbiting 1,500 feet south of SGZ at an altitude of about 800 feet above ground at 15 minutes before zero time. The low-altitude monitoring helicopter that crashed had been replaced with a Marine Corps UH-43D helicopter, and it was orbiting 1,500 feet north of SGZ about 800 feet above the ground at 15 minutes before zero time.

Required countdowns began on radio nets 1, 2, 6, and 8. At 10 minutes prior to detonation the siren on the CP-1 building ran for 30 seconds, and the red lights on top of the building were turned on until after detonation.

MARSHMALLOW zero time was 1000 hours PDT on 28 June 1962.

Immediately following detonation, a small dust cloud was observed over SGZ. Two passes were made over this cloud by Air Force and PHS personnel in the U-3A aircraft: one at 1006 hours and 7,100 feet MSL and the other at 1009 hours and 6,000 feet. The portal area elevation is 5,430 feet MSL. On both passes, readings were at background levels.

During this time, a low-altitude helicopter survey of the portal and trailer park areas was begun. Indicated ground level exposure rates were considerably less than amounts necessary to damage film records in the trailer park. Radiation levels of several R/h and increasing were indicated in a localized area around the vent pipe from 15 to 20 minutes after zero time. However, this effluent was more than 600 feet upslope from the trailer park, was diluted rapidly as it rose and moved north, and would not affect films in the trailer park area.

The U-3A aircraft detected 0.2 mR/h at 1012 hours flying 400 feet from the portal. Effluent from the vent pipe and portal was monitored as the low-level cloud moved north toward Area 12. The highest reading in the cloud was 8 mR/h 200 feet above the surface and one-half mile north of SGZ at 1038 hours. The highest reading in the portal area was 32 mR/h at 1042 hours, 100 feet from the entrance to the tunnel.

Estimated cloud width three miles north of SGZ was one mile, and at Area 12 Camp, the cloud was four miles wide and centered over the Camp. Measurements below 5 mR/h were with Precision 111 Scintillator detectors, below 20 mR/h with Beckman MX-5 GM instruments, and above 20 mR/h with AN/PDR 39/T1B survey instruments. Table 5.1 lists readings obtained by PHS monitors during the aerial survey.

5.3.1 Test Area Monitoring

Telemetry units on the surface read background until five minutes after detonation when 18 mR/h was indicated by units north and south of the vent hole. These readings increased rapidly to 14 R/h at 15 minutes after zero time, and to a maximum of 200 R/h at 1125 hours. Intensities generally decreased but fluctuated thereafter at the vent hole. Readings from the two units were 3.5 and 6 R/h by midnight.

The two units inside the trailer park read background until they failed to respond at 12 minutes after zero time. Units

TABLE 5.1

MARSHMALLOW EVENT

PHS AERIAL RADIATION SURVEY RESULTS
28 June 1962

Time	Location	Elevation (feet) (MSL unless otherwise noted)	Gamma (mR/h)
1006	SGZ	7100	Bkg*
1009	SGZ	6000	Bkg
1012	SGZ	400 above portal	0.2
1022	SGZ	6800	4.0
1035	One mile N of SGZ	7000	1.0
1038	One mile N of SGZ	200 above surface	3.0
1038	One half mile N of SGZ	200 above surface	8.0
1039	Portal	100 above portal	14.0
1042	Portal	100 above portal	32.0
1045	One mile N of SGZ	7000	1.0
1056	Area 12 Camp	7100	Bkg
1057	One mile S of Area 12 Camp	7000	0.5
1100	3 miles N of SGZ	7000	1.5
1104	Portal	200 above portal	8.0
1122	Area 12 Camp	7000	0.1
1123	One mile S of Area 12 Camp	7000	0.3
1127	One mile N of SGZ	7000	2.0
1127	Portal	200 above portal	20.0
1135	Area 12 Camp	7000	0.4

*Background Radiation Measurement

north and south outside the trailer park measured 1 mR/h and 3 mR/h, respectively, nine minutes after zero time, indicated 2 R/h and 1.2 R/h 20 minutes after zero time, and fluctuated below 100 mR/h the rest of the day. Generally higher readings at the trailer park during the night apparently resulted from descending cooler air bringing radioactive gases down from the vent pipe about 600 feet away.

The tunnel portal unit indicated background until 15 minutes after zero time when it measured 6.5 mR/h. The maximum portal reading on event day was 70 mR/h at 1430 hrs, and this unit indicated 3 mR/h by 2400 hours.

Background readings were indicated by the main and FCP road unit except for three readings less than 1 mR/h from 1530 to 1615 hours on event day. The unit three miles south of the portal indicated background from zero time until 1230 hours when circuit damage occurred.

Telemetry units in the tunnel indicated background one minute after zero time except for the 8+65 crossdrift unit which read 40 R/h. All units measured radiation above background by zero time plus 12 minutes, and had reached their highest readings by 45 minutes after zero time. The maximum outside the gas seal door was 1.6 R/h, and at crossdrift 8+00 was greater than 10,000 R/h.

Radsafe began the initial ground radiation survey at 1055 hours as requested by the DOD Test Group Director. Three two-man monitor teams and a supervisor were dressed in full radex clothing and MSA all-service gas masks. Their equipment consisted of explosimeters, carbon monoxide detectors, beta-gamma detectors, alpha detectors, and a velometer. These personnel monitored roads to the portal and instrumentation areas, office trailers in the portal area, and the vent hole area.

The teams proceeded in vehicles along the Pole Line Road to the Area 16 main access road and then to the tunnel portal area surveying enroute. Survey data were reported via net 3 radio when radiation measurements were made. After the portal entrance was surveyed, radex area control was established near the office trailer park. A temporary mobile check station was established at this location. The route to the film and instrumentation trailer park was surveyed and the vent hole area was checked for radioactivity and toxic gases.

Survey data confirmed telemetry unit readings at all surface locations, except monitors did not approach closer than 20 feet to the units adjacent to the vent hole. The vent hole was monitored first from a distance of 200 feet, where the exposure rate was 125 mR/h. At 20 feet the exposure rate was 2 R/h. After taking this reading, the team returned to the mobile check station controlling the portal radex area.

Each area and all contaminated or radioactive materials were marked to indicate radiation levels. Personnel entering radiation areas or working with contaminated material were briefed concerning potential exposure and safety precautions, and were provided with anticontamination clothing, equipment, and material.

5.3.2 Surface Reentry and Recoveries

Radiation surveys and surface reentries on event day were controlled by CTO Operations from the FCP. The first objective of reentry was to recover film records from the trailer park. Radiation intensities had not been high enough to damage films, and personnel exposure rates during film recovery were only 10 to 40 mR/h. Exposure rates in the portal area were a maximum of 5 mR/h during recoveries. Radsafe Area Access Registers indicated 13 EG&G, six LMSC, five Sandia, four SRI, one Air Force, one

Army, and one DASA personnel were processed through the check station to recover experiment data in the portal area and above the tunnel. Highest exposures indicated for these personnel by pocket dosimeters were 50 mR.

5.4 POSTEVENT ACTIVITIES

Radsafe continued telemetry readouts until 0800 hours 5 July. Radiation surveys of the vent hole continued, and radex area requirements in the portal area were maintained. Tunnel access had been controlled by security from 0600 hours on D-1 with entry limited to personnel possessing "Q" clearances, military top secret, or military secret clearances. This access control was continued through D+3.

5.4.1 Tunnel Reentry

Each participant in tunnel reentry operations was certified by the Bureau of Mines as having satisfactorily completed training in the use of the two-hour McCaa breathing apparatus, along with instruction in mine rescue procedures.

By 0845 29 June, D+1, all surface telemetry units except those at the vent pipe were reading background, the unit outside the gas seal door indicated 7 mR/h, and the unit inside the door read 9 R/h.

The initial reentry team consisted of a Chief of Party, radiation and industrial safety monitor, mining engineer, and miner. Each member was provided with sets of required anticontamination clothing; two self-reading pocket dosimeters (0-200 mR, 0-5 R); one two-hour McCaa breathing device; a Bureau of Mines-approved, hat-mounted miner's light with battery pack; and an MSA-approved explosive-proof flashlight. Members of a second team (rescue party) were on standby in case they were needed.

The reentry team entered the tunnel to the gas seal door. A section of the tunnel vent line had been removed at the door prior to the event, and a sealing plate had been bolted to the flange of the vent pipe where it penetrated the gas seal door. The flange plate was removed, the vent line was reinstalled, and the party left the tunnel.

The vent line fan apparently was turned on between 1205 hours and 1210 hours when readings of the telemetry unit outside the gas seal door rose from 5 mR/h to 50 mR/h. By 1245 hours, the reading from this detector increased to its maximum of 1.3 R/h. This reading decreased steadily to 100 mR/h by 1400 hours, 50 mR/h by midnight, and 2.5 mR/h by midnight of the next day, 30 June.

Units at the portal and at the junction of the portal area with the access road were reading background after the vent line fan was turned on until 1235 hours, when the portal unit indicated 1.5 R/h and the junction unit 1 mR/h. The junction unit peak reading was 13 mR/h at 1400 hours. Readings of a few mR/h continued through the day. The portal unit maximum measurement was 4.5 R/h at 1300 hours on 29 June, and measurements from 1900 hours through 2400 hours were 2 R/h. Critical data recovery from the tunnel was complete on 2 July, D+4 days. By 2400 hours on 2 July, the portal unit read 83 mR/h, outside the gas seal door was 1.7 mR/h, inside the door was 13 mR/h, the Y unit read 90 mR/h, the camera station 42 mR/h, crossdrift 8+65 61 mR/h, and crossdrift 8+00 570 mR/h.

5.4.2 Sample Recovery, Mining and Drilling Operations

Decontamination units were positioned at entrances to contaminated areas. Personnel and equipment were monitored and decontaminated as necessary. Drill rigs and associated equipment used in postevent activities also were monitored and decontaminated, as necessary.

Sample recovery from the LOS pipe was begun 5 July and was completed 12 August, 1962. Telemetry readings at 0800 hours on 5 July, when readings were terminated, were 1.3 mR/h outside and 5.5 mR/h inside the gas seal door, 40 mR/h at the Y, 30 mR/h at the camera station, 32 mR/h at crossdrift 8+65, and 250 mR/h at crossdrift 8+00. The portal unit read 45 mR/h.

Postevent mining to clear debris, to investigate rock stresses, and to explore areas near GZ continued intermittently until 22 August 1963. Postevent drilling operations proceeded without incident and without radex requirements except when drill depth was near GZ. Drilling was from a leveled area high above the tunnel (see Figure 5.1). However, access was by a road on the southwest side of the mountain, away from the portal.

5.5 RESULTS AND CONCLUSIONS

Maximum gamma radiation intensities outside the tunnel were 200 R/h at the vent hole southeast telemetry unit on event day at 1125 hours, and 4.5 R/h at the tunnel portal on 29 June at 1300 hours. The tunnel telemetry unit at crossdrift 8+00 indicated greater than 10,000 R/h from nine minutes until 30 minutes after detonation.

Checks were made for toxic gases and explosive mixtures. On 28 June 1962, a survey of the portal and vent line area showed less than 50 ppm carbon monoxide and no detectable carbon dioxide or nitrous oxides. Surveys were continued through 22 August 1962 with no detectable toxic gases or explosive mixtures present.

Personnel exposures received during individual entries to MARSHMALLOW radex areas from 28 June 1962 through 22 August 1963 are summarized below. Average exposures are from self-reading pocket dosimeters as recorded on Area Access Registers. Maximum exposures are from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	1,447	460	77
DOD Participants	227	460	79

No radiation levels above background were detected offsite. During postevent tunnel reentry operations, no ground-deposited radioactivity was detected at the work site or any other NTS work location from the minor releases of gaseous radioactivity.

CHAPTER 6

MUDPACK EVENT

6.1 EVENT SUMMARY

MUDPACK was a DOD-sponsored underground nuclear detonation with a yield of 2.7 kt conducted at 1210 hours PST on 16 December 1964 at shaft site U10n in Area 10 of the NTS. The device was emplaced in a 24-inch diameter shaft at a depth of 500 feet. MUDPACK was a weapons effects test designed to obtain information concerning ground shock.

No radioactivity above normal background levels was detected onsite by ground and aerial monitoring teams or offsite by ground monitoring and stationary dose rate recorders, or in any environmental samples either after the detonation or after subsequent sample recovery operations.

6.2 PREEVENT ACTIVITIES

6.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all MUDPACK project activities in Area 10. Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Field Command, DASA, and the AEC Albuquerque Operations Office. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

6.2.2 Planning and Preparations

The "MUDPACK Reentry Plan" described preevent preparations and postevent procedures used to conduct a safe and economical reentry.

A. Radiological Safety Support

A detailed radiological safety reentry plan was submitted to participating agencies prior to each event. Test area maps with appropriate reference points were prepared. Reference markers, radiation decay recorders, and air sampling equipment were positioned in the test area. Reentry routes into the test area were established during "dry runs." Party monitors were briefed regarding surface reentry, sample recovery, manned stations, and security station requirements.

All personnel at manned stations were provided with appropriate anticontamination clothing and equipment, and Radsafe monitors were in attendance.

Anticontamination equipment and materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

B. Telemetry and Air Sampling Support

Remote Area Monitoring System units for the MUDPACK event were located as follows:

Station 1	- SGZ
Stations 2 through 9	- on the 500-foot arc at 45-degree intervals

Stations 10 through 17 - on the 2,500-foot arc at 45-degree intervals

Air sampling units were located as follows:

- 8 - on the 1,000-foot arc (trailers with recorders) at 45-degree intervals beginning at 0°
- 8 - on the 1,000-foot arc (satellite samplers) at 45-degree intervals beginning at 22.5°

Each trailer with recorder had a satellite sampler attached to it by means of an electric cord. Thus, if an air sampling trailer with recorder was positioned at 45 degrees, the satellite sampler was at 67.5 degrees.

C. Security Coverage

Muster and control stations were established on event day. The muster station was south of BJY on the Mercury Highway. Three hours prior to scheduled device detonation, all personnel were clear of the area except the arming party and others who were authorized to remain. From two hours before planned device detonation to 30 minutes before planned device detonation, USAF and security personnel made a final aerial sweep of the closed portion of Area 10 in an L-20 aircraft. Radsafe monitors were stationed at all Federal Services, Inc. (FSI), security roadblocks and work areas within the exclusion area. Control of the area was maintained by the use of roadblocks, access permits, and a "Schedule of Events". Parties could enter the controlled area only if they were listed on the Test Manager's "Schedule of Events", or with permission of the Test Group Director.

D. Air Support

In addition to the L-20 aircraft for security sweeps, aerial monitoring was performed by USAF and PHS cloud tracking teams in Air Force U-3A and C-45 aircraft. DOD personnel conducted an aerial photo mission in a UH-43D helicopter.

6.2.3 Late Preevent Activities

On 15 December (D-1 day), DASA, SC, USC&GS, and DOD photo party personnel were in the closed area. DASA representatives were there to coordinate overall event activities. Final instrumentation adjustments were made by SC personnel, and completion of seismic instrument installation was performed by USC&GS personnel. Photographic equipment was set up at a manned station in the closed area by the DOD still photo party.

6.3 EVENT-DAY ACTIVITIES

Final preparation of instrumentation and facility button up was performed during the predawn hours on event day. Air samplers were put on continuous sampling mode by manned station Radsafe personnel three hours before scheduled detonation. There were two Radsafe manned stations within the exclusion area. Each consisted of two monitors in vehicles equipped with net 3 and net 10 radios.

A final weather briefing for the Test Manager and Advisory Panel was conducted two hours prior to scheduled device detonation. Forty-five minutes before scheduled device detonation, the DOD photo aircraft took its position.

Required countdowns began at 1140 hours on radio nets 1, 2, 6, and 8. Ten minutes before detonation, the siren on the CP-1 building ran for 30 seconds, and the red lights on top of the building were turned on until after detonation time.

MUDPACK zero time was 1210 hours PST on 16 December 1964.

Fourteen low passes over SGZ by the U-3A cloud tracking aircraft resulted in only background readings. Three more low passes over SGZ after collapse time also indicated background readings. Monitoring was terminated at 1240 hours and the mission was completed at 1305 hours.

MUDPACK telemetry readings were background from zero time until telemetry was discontinued at 2400 hours on 19 December 1964. The initial radiation survey began at 1330 hours and terminated at 1400 hours on 16 December 1964. Only low levels of radiation above background were detected, and these positive readings were from another event earlier that day. Survey data are shown in Table 6.1.

A postevent aerial photo survey was conducted by American Aerial Survey (AAS) personnel in a Cessna 185 on event day.

6.4 POSTEVENT ACTIVITIES

6.4.1 Postevent Drilling

Postevent drilling operations were conducted on three separate occasions for this event. The first operation began on 18 December 1964 and was accomplished using two drill rigs, PS-1V and PS-1A. PS-1V completed core sampling on 19 December at 1700 hours. The abandonment valve was closed at 2030 hours the same day. Forty-three core samples with a maximum contact reading of 9 R/h were recovered. PS-1A completed core sampling at 1805

TABLE 6.1

MUDPACK EVENT

INITIAL RADIATION SURVEY DATA

16 December 1964

Time	Location (from SGZ)	Exposure Rate* (mR/h)
1320	Radsafe road stake 2N3 (3-1/4 miles SW)	0.10
1322	Radsafe road stake 2K2 (2-1/2 miles SW)	0.10
1324	Radsafe road stake 10A14 (1-1/2 miles S)	0.15
1325	Radsafe road stake 10A16 (1-1/4 miles S)	0.15
1330	East perimeter fence	0.25
1332	Northeast perimeter fence	0.35
1334	North perimeter fence	0.40
1336	Northwest perimeter fence	0.25
1338	West perimeter fence	0.25
1340	Southwest perimeter fence	0.25
1348	South perimeter fence	0.15
1350	Southeast perimeter fence	0.20
1400	Ground zero crater	0.40
1410	Cables	0.40
1410	Red shack	0.40
1425	Cable equipment removal	0.40

*Radioactivity measured was from another event detonation earlier on 16 December 1964.

hours on 19 December. The abandonment valve was closed at 2050 hours on the same day. Twenty core samples with a maximum contact reading of 38 R/h were recovered.

PS-1A was reopened by sidetrack drilling for further coring operations on 6 January 1965. The coring operation began at 0835 on 11 January. Nine samples were taken with a maximum contact reading greater than 200 mR/h. Coring operations were complete and the abandonment valve closed at 0215 hours on 12 January 1965.

On 2 February 1965, PS-1A was again reopened by sidetrack drilling at 1300 hours. Coring operations were complete at 0225 hours and the abandonment valve was closed at approximately 1200 hours on 3 February. Twenty-two core samples with a maximum contact reading of 900 mR/h were recovered.

6.4.2 Industrial Safety

On each shift during the drilling operations, checks were made for toxic gases and explosive mixtures. These measurements then were recorded in the Radsafe monitors' log books. Industrial safety codes, including specific codes for drilling, were established by REECo and were emphasized during all operations.

6.5 RESULTS AND CONCLUSIONS

Telemetry coverage began at zero time, 16 December 1964, and continued until midnight on 19 December 1964. No readings above background were detected.

During drillback operations, the maximum radiation reading on the rig platform was 6.6 mR/h at PS-1V on 19 December 1964.

No alpha radiation, toxic gases, or explosive mixtures were detected.

Personnel exposures received during individual entries to the MUDPACK postevent drilling area from 18 December 1964 through 3 February 1965 are summarized below. The average exposure is from self-reading pocket dosimeter readings as recorded on Area Access Registers. The maximum exposure is from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	243	40	0.9

It was the opinion of the PHS that no radioactive contamination of the offsite area resulted from the MUDPACK event.

CHAPTER 7

WISHBONE EVENT

7.1 EVENT SUMMARY

The WISHBONE event was a joint DOD-LRL underground detonation with a yield less than 20 kt conducted at 0819 hours PST on 18 February 1965, at shaft site U5a in Area 5 of the NTS. Device emplacement was in a 48-inch diameter shaft at a depth of approximately 600 feet (Figure 7.1). WISHBONE was a weapons effects test to determine the response of equipment and materials in a nuclear detonation environment. The event included eleven DOD scientific projects.

Surface collapse occurred about seven minutes after detonation and produced a subsidence crater approximately 450 feet in diameter and 75 feet deep. Initial gamma radiation and induced radioactivity were detected in the SGZ area at detonation time. Four minutes after device detonation, minor seepage of radioactive effluent began, producing a maximum reading of 140 mR/h at the west remote area monitoring station on the 2,500-foot arc. This reading decreased to background by six hours after device detonation. No radioactivity was detected offsite.

7.2 PREEVENT ACTIVITIES

7.2.1 Responsibilities

The LRL Test Group Director was responsible for safe conduct of all WISHBONE project activities in Area 5. Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate

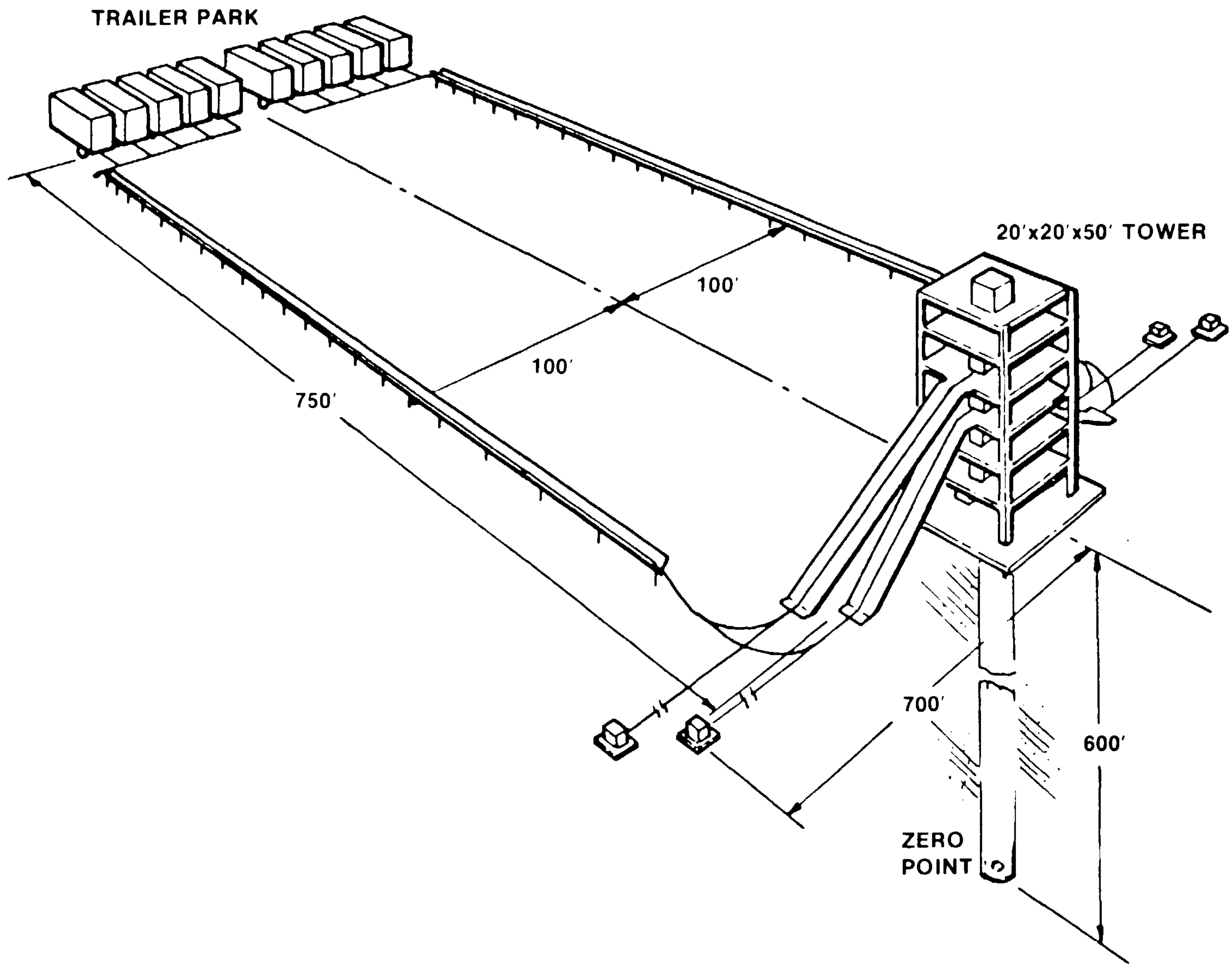

Figure 7.1 WISHBONE Test Configuration

action between Field Command, DASA, and the AEC Albuquerque Operations Office. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

7.2.2 Planning and Preparations

The "WISHBONE Reentry Plan" described preevent preparations and postevent procedures used to conduct a safe and economical reentry and recovery within the desired time frame. As shown in Figure 7.1, test materials were mounted at several levels on a tower above the LOS pipe. Also as shown in Figure 7.1, test materials requiring early recovery were on sleds which were winched down ramps immediately after detonation to locations outside the subsidence crater which formed later. This both preserved test materials and facilitated early recovery. Radsafe personnel were provided with "Detailed Initial Reentry Procedures" for reentry and sample recovery operations.

A. Radiological Safety Support

Detailed radiological safety reentry plans were submitted to participating agencies prior to the test event. Test area maps with appropriate reference points were prepared. Reference markers, radiation decay recorders, and air sampling equipment were positioned in the test area. Reentry routes into the test area were established during "dry runs." Party monitors were briefed regarding surface reentry, sample recovery, manned stations, and security station requirements.

All remote area monitoring stations and air sampling units were installed according to DOD and LRL specifications prior to D-5 days. Radsafe monitors were stationed at all Wackenhut Security, Inc. (WSI), security roadblocks and work areas within the exclusion area to perform surveys and provide other support as directed. There were two Radsafe manned stations within the exclusion area. Each consisted of two monitors in vehicles equipped with net 3 and net 10 radios.

Radsafe manned stations had as a primary mission the documentation of any radioactive effluent released. All personnel at manned stations were provided with appropriate anticontamination clothing and equipment, and Radsafe monitors were in attendance.

Radsafe provided monitoring teams and supervisory personnel for initial surface radiation surveys, aerial surveys by helicopter, and reentry parties as needed. Radsafe personnel were standing by at the FCP prior to detonation to perform surveys; provide emergency support as directed; provide and issue anticontamination equipment and material, portable instruments and dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination as required.

Anticontamination materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

A mobile facility for issue of anticontamination equipment, portable instruments, and dosimetric devices was positioned at the FCP along with a mobile decontamination unit.

B. Telemetry and Air Sampling Support

RAMS units were located as follows:

Station 1	- SGZ
Stations 2 through 9	- 500-foot arc at 45-degree intervals beginning at 0°
Stations 10 through 25	- 2,500-foot arc at 22.5-degree intervals beginning at 0°

Air sampling units were in operation at zero time with detector recorders in the following locations:

8 - 1,000-foot arc (trailers with recorders) at 45-degree intervals beginning at 0°
8 - 1,000-foot arc (satellites) at 45-degree intervals beginning at 22.5°
16 - 2,000-foot arc (trailers with recorders)
16 - Remote Area Gas Sampler (RAGS) units at 500-foot perimeter fence

Samplers were started and set on continuous sampling mode by the manned station teams five hours before device detonation.

PHS air samplers were operating at 65 stations in the offsite area, and 24-hour sample filters were collected daily. Stationary dose-rate recorders were operating at 21 offsite locations. Fifteen PHS personnel were on duty for surveillance activities during and after this event.

C. Security Coverage

On D-day, a muster station was established on the main access road to Frenchman Lake at the junction with Mercury Highway, and a control station was established on the Short Pole Line Road at the junction with Mercury Highway.

WSI security personnel performed sweeps of the closed area and issued muster badges to all personnel. The L-20 aircraft checked outlying areas for incoming traffic.

D. Air Support

Security used a USAF L-20 and pilot for sweeps of the closed area and surrounding terrain, and a DOD photo party with a Radsafe monitor was provided a USAF H-21 helicopter with pilot and copilot.

The USAF and PHS provided aerial monitoring and sampling services for the WISHBONE event. Two USAF C-45 aircraft code-named Vegas I and Vegas II were provided for cloud sampling and measurements. In addition, a PHS Aerocommander aircraft code-named Vegas III, a USAF U-3A and a USAF C-54 were provided for cloud tracking purposes.

Vegas I carried a cryogenic sampling system, an electrostatic precipitator sampling train, and a cascade impactor for air sampling and cloud monitoring. The electronic instruments carried by Vegas II were a suitcase analyzer, an EG&G aerial monitor, and a Victoreen Radector. The EG&G aerial monitor had a range of 0.2 mR/h to 2,000 mR/h. The Victoreen Radector had an upper limit of 50 R/h.

Vegas II carried a flow-through ionization chamber connected to a vibrating reed electrometer and a Precision

111 scintillation detector with a range of 0 to 5 mR/h for cloud height measurements. An air sampler with an E-500B probe was mounted internally for verification. The E-500B was an Eberline instrument with an upper range of 2,000 mR/h and was used to indicate peak gamma readings above the 5 mR/h limit of the scintillation detector. All of these instruments were connected to Esterline-Angus strip chart recorders.

7.3 EVENT-DAY ACTIVITIES

The arming party entered the closed area at 0310 hours on 18 February, after receiving permission to arm the device from the Test Manager. DOD photo parties were at manned stations at 0455. Radsafe initial radiation survey teams were at the muster station at 0500 hours. At 0600, two Sandia, two EG&G, six LRL, and five WSI personnel were the only persons in the closed area in addition to the manned station personnel. By 0700, the AEC Operations Coordination Center had closed Mercury Highway to traffic. WSI security personnel cleared the closed area of all personnel and completed a final ground security sweep.

The final weather briefing for the Test Manager and Advisory Panel was conducted approximately two hours prior to planned device detonation. From two hours before planned device detonation to 20 minutes before device detonation, USAF and security personnel in an L-20 aircraft made a final aerial sweep of the closed portion of Area 5.

The required countdown began on radio nets 1, 2, 6 and 8. At ten minutes prior to device detonation, the siren on the CP-1 building ran for 30 seconds, and the red lights on top of the building were turned on until after detonation.

WISHBONE zero time was 0819 hours PST on 18 February 1965.

The SGZ telemetry unit indicated 800 R/h at zero time, 325 R/h at 0821, and 300 R/h at 0823 hours before the circuit was broken by surface subsidence. All of the RAMS units on the 500-foot arc (Stations 2-9) showed gamma radiation from SGZ at zero time. This was initial radiation and induced activity from experiments and structures. The typical RAMS unit response was less than 1 R/h which dropped immediately to about 125 mR/h with decay recorded from this point.

The first indication of a release (increase above decreasing readings) was observed at 0823 hours on the west 500-foot arc station. The maximum reading of 250 mR/h occurred at 0825 hours.

Cavity collapse occurred at approximately 0826 hours. By 0831, the west 500-foot station readings had dropped to 12 mR/h. At 0832, readings again began to rise at this location, reaching a maximum of 30 mR/h at 0834 hours. By 0834, the major portion of the early release had ceased, and calculation of gross release at this time indicated about 2×10^3 curies of radioactivity had been released to the atmosphere.

Air samplers on the 1,000-foot arc remained on continuous sampling mode, and filters were collected every four hours after the initial pickup (1241 to 1412 hours on 18 February) until it was determined there was no further release. After this determination, the sample filters were collected every eight hours.

All samplers remained in operation until 1310 hours on 18 February 1965, at which time the 16 outer-arc samplers were shut down. The sampling array during the balance of postevent operations was the same as at zero time on the 1,000-foot arc. Sampling was discontinued at 1150 hours on 8 March. However, air samples were collected in working areas during all active phases of the postevent recovery operation.

7.3.1 Aerial Radiation Surveys

The aircraft previously mentioned under Air Support were available at zero time with the exception of Vegas I, which aborted the mission due to mechanical problems.

Vegas II took off from Las Vegas at 0715 hours on 18 February, and arrived over Frenchman Flat at 0830. All sampling systems were started at 0857 hours. While the suitcase analyzer indicated the presence of radioactivity, no positive radiation readings were indicated by the other instruments. Sampling was completed at 0937 and Vegas II landed in Las Vegas at 1010.

Vegas III terminated its mission after detecting no radioactivity.

7.3.2 Test Area Radiation Surveys and Reentry Activities

The initial radiation survey of areas away from SGZ began at 0832 hours and was completed at 1001 hours by Radsafe monitoring personnel. The only readings above background were 0.4 mR/h at 0900, 3 mR/h at 0915, and 0.07 mR/h at 0954 hours one and three-quarter miles west-southwest of SGZ. All survey data were reported to the net 3 radio control operator when measurements were made.

Each area and all contaminated or radioactive materials were marked to indicate radiation levels. Personnel entering radex areas or working with contaminated material were briefed concerning potential exposure and safety precautions, and provided with anticontamination clothing, equipment, and materials.

At 0835 hours the SGZ area LRL radiation survey team departed from the roadblock at the intersection of Cane Springs Road and Mercury Highway. The trailer compound had been surveyed by 0845, with a maximum reading of 2-3 mR/h reported. No alpha activity was detected, and by the time film recovery parties were allowed into the area (0930 hours), all radiation readings were near background. An air "grab" sample was collected at 1130 hours in the crater and analyzed by LRL.

Organizations having personnel in the radex area during experiment recovery were Harry Diamond Laboratories (HDL), Bell Telephone Laboratories (BTL), Lockheed Missile and Space Corp. (LMSC), Northrup Corp. (NC), Boeing Aircraft Co. (BAC), Naval Ordnance Lab. (NOL), AFWL, LRL, LASL, and SC.

Recovery personnel entered the crater area at 1230 hours. The average exposure of ten recovery personnel indicated by pocket dosimeter readings was 300 mR and the maximum exposure was 700 mR. Sleds 1, 2, 3, and 4 were surveyed by 1330 hours. Results of this survey are shown as Table 7.1. By 1430 hours, the crater survey was complete with a maximum of 6 R/h reported over the SGZ area. No alpha activity was detected.

At 1630 hours the closure valve and emplacement casing had been filled with Cal-Seal, but bubbles were observed coming through the fill. Security guards were placed in critical locations at 1700 to provide surveillance of the crater and skids while postevent drilling preparations continued. It appeared that the Cal-Seal had reduced the release-rate significantly by 1800 hours, and postevent drilling began.

7.4 POSTEVENT ACTIVITIES

At 2005 hours, Radsafe reported 30 mR/h gamma and 90 mrad/h

TABLE 7.1

RADIATION SURVEY OF SLEDS - 18 FEBRUARY 1965

Sled No.	Time of Survey	Measurement Distance (Approx.)	Gamma
1	1110	1 foot	10 R/h
2	1110	Contact	10 R/h
	1330	Contact (center)	12 R/h
	1330	Contact (sides)	4 R/h
3	1100	Contact	1 R/h
	1100	3 feet	0.1 R/h
4	1100	Contact	0.15 R/h
	1100	1 meter	0.02 R/h

beta-gamma on the drill rig platform, and the operation was suspended until air samples could be collected and analyzed. A five-minute high-volume air sample collected by Radsafe on the rig platform at 2045 hours read 1.5 mR/h on the charcoal cartridge and 150 mR/h on the prefilter (as read with a portable instrument).

Drillers returned to work at 2115 hours after Radsafe was instructed to keep respirators on all personnel in the crater or postevent drilling work areas whenever the readings went above 1 mR/h. By 2130 hours, the air sample had been analyzed and radionuclides on the prefilter and in the charcoal cartridge identified. At about 2200 hours, the RAMS units on the 500-foot arc began to indicate increased activity again. A survey of the SGZ area at 2315 hours revealed a small hole leaking gas through the Cal-Seal plug in the emplacement casing. The contact reading was 1 R/h (about 5-10 times background in that area).

On 19 February at 0010 hours an undercut area beneath the concrete pad in the crater at SGZ was discovered, with readings of 1 R/h reported. Drilling operations (below the concrete pad) began on PS-1A hole at 0440 hours on this date. Seepage from the SGZ area continued to be detected on the 500-foot RAMS perimeter. At 1445 hours Cal-Seal had been poured into the undercut, reducing the readings to 100 mR/h. However, as soon as that seepage had been reduced at that location, readings of 3 R/h were detected on the north and west edges of the pad. Coring on PS-1A was completed at 0910 hours on 20 February. Thirty-six core samples with a maximum contact reading of 80 R/h were recovered.

The second drilling operation (PS-1AS) began at 1212 hours on 20 February by beginning a sidetrack at a depth of 520 feet. Total depth was attained at 1900 hours and coring began at 2050 hours. Coring was completed at 0055 hours on 21 February. Drilling operations were suspended until 25 February.

The third drilling operation (PS-1ASS) began at 2350 hours on 25 February by beginning a second sidetrack at a depth of 526 feet. Total depth was reached at 1100 hours at 26 February. Operations were normal from 0830 hours to 1100 hours. At that time, a slight increase in radiation levels (3 mR/h on the platform and 7 mR/h on the casing) was seen on the RAMS readouts in the Radsafe base station trailer. An immediate check was made with portable instruments but nothing was detected.

No additional release was detected until 1340 hours when a reading of 10 mR/h was observed on the casing. All personnel working on the rig immediately put on full-face masks, and a 15-minute air sample was taken. The sample read 1 mrad/h beta plus gamma and 0.5 mR/h gamma. Personnel working on the platform wore the full-face masks for approximately 15 minutes. After this, only the person guiding the coring tool into the drill pipe was required to wear a mask. This was a precautionary measure since a small amount of gas occasionally would escape from the open drill pipe. Occasional release of gas continued until coring was completed at 1530 hours on 26 February.

The fourth drilling operation (PS-1ASSS) was started at 1730 hours on 26 February by beginning another sidetrack at a depth of 487 feet. Total depth was reached at 2100 hours and coring began. The coring operation was completed at 0555 hours on 27 February. A toxic gas concentration of 15,000 ppm CO was detected in the open end of the drill pipe at 0640 hours, and 100 percent of the LEL for explosive mixtures was measured. Ten minutes later, released activity was measured by holding the probe of a Geiger-Mueller tube instrument in the open end of the drill pipe. The instrument indicated approximately 40 mrad/h beta plus gamma and approximately 8 mR/h gamma.

Pumping drill mud down the pipe appeared to stop this release. However, by 0700 hours releases of increased intensity had been detected with readings up to 130 mrad/h beta plus gamma and 40 mR/h gamma, being measured in the open end of the drill pipe. A constantly running high-volume air sampler was installed on the drill rig mast and monitored carefully. It ran approximately 1.5 hours and reached a maximum of 1.2 mrad/h beta plus gamma and 0.5 mR/h gamma contact on the charcoal filter. The Whatman 41 prefilter read somewhat less.

On 1 March 1965, the drill pipe was removed from PS-1A and the abandonment valve closed at 1510 hours. Miscellaneous operations in the U5a crater continued until 18 March. However, no significant radiological problems were encountered.

7.5 RESULTS AND CONCLUSIONS

Telemetry coverage began at zero time and was discontinued on 21 February 1965. On 25 February, it was begun again and continued until 0800 hours on 8 March 1965. The highest telemetry reading of 800 R/h was at SGZ one minute after detonation.

The maximum gamma intensity during postevent drilling was 40 mR/h at 0650 hours at the PS-1ASSS open drill pipe on 27 February 1965. Maximum toxic gas and explosive mixture readings were 15,000 ppm CO and 100 percent of the LEL at 0640 hours at this location on the same date.

Personnel exposures received during individual entries to WISHBONE radex areas from 18 February 1965 through 18 March 1965 are summarized below. Average exposures are from self-reading pocket dosimeters as recorded on Area Access Registers. Maximum exposures are from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	1,085	1,160	11
DOD Participants	68	1,160	39

Urinalyses for radioiodines preliminary to thyroid counts were completed on a total of 121 persons. Twenty-two measurable thyroid activities were recorded. Eight thyroid doses were one rem or more, and the highest was 9.3 rem compared to the quarterly guide of 10 rem and the annual guide of 30 rem in 1965.

It was the opinion of the PHS that no radioactive contamination of the offsite area resulted from the WISHBONE event.

CHAPTER 8

GUMDROP EVENT

8.1 EVENT SUMMARY

The GUMDROP event was a DOD-sponsored underground nuclear detonation with a yield less than 20 kt conducted at 1400 hours PST on 21 April 1965 at tunnel site U16a.02 in Area 16 of the NTS. The device was emplaced at the end of a 1,050-foot drift, which continued from the existing U16a.01 LOS tunnel, at a depth of 834 feet. GUMDROP was a weapons effects test which investigated the response of equipment and materials to a nuclear detonation environment. There were 12 DOD scientific projects conducted by laboratories and contractors.

Cavity collapse occurred seven minutes and 23 seconds after zero time. Containment was successful and reentry activities proceeded on schedule. No radioactivity above normal background levels was detected onsite by ground and aerial monitoring teams or offsite by ground and aerial monitoring, by stationary dose rate recorders, or in any environmental samples.

There was a controlled release of radioactivity from H+3.5 hours to H+44 hours through the filtered vent line system. Activity released primarily consisted of noble gases and they dissipated rapidly in the atmosphere.

8.2 PREEVENT ACTIVITIES

8.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all GUMDROP project activities in Area 16. Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Field Command, DASA, and the AEC Albuquerque Operations Office. Sandia Corporation was responsible for timing and firing systems, and EG&G personnel were responsible for arming and firing the device. Sandia Corporation also was responsible for stemming design, and for installation of necessary measuring devices and equipment to indicate the postevent tunnel condition. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

8.2.2 Planning and Preparations

The "GUMDROP Reentry Plan" described preevent preparations and postevent procedures used to produce safe and economical reentry and recovery within the desired time frame. Stemming design incorporated necessary provisions to maximize safety of reentry. Figure 8.1 shows the GUMDROP tunnel layout. "W. P." indicates "Working Point" or GZ, and the tunnel continues to the right through the previously constructed MARSHMALLOW tunnel to the portal.

A. Tunnel Structural Conditions

Tunnel condition monitors (TCM's) were installed to indicate postevent structural conditions. These monitors each consisted of a wooden box designed to crush or deform under the conditions existing during tunnel collapse, but durable enough to withstand considerable shock due to falling debris. Upon crushing, a plastic guillotine cut interior wiring to effect a change in circuit resistance. Each TCM used a pair of signal wires to conduct the signal to the reentry safety trailer.

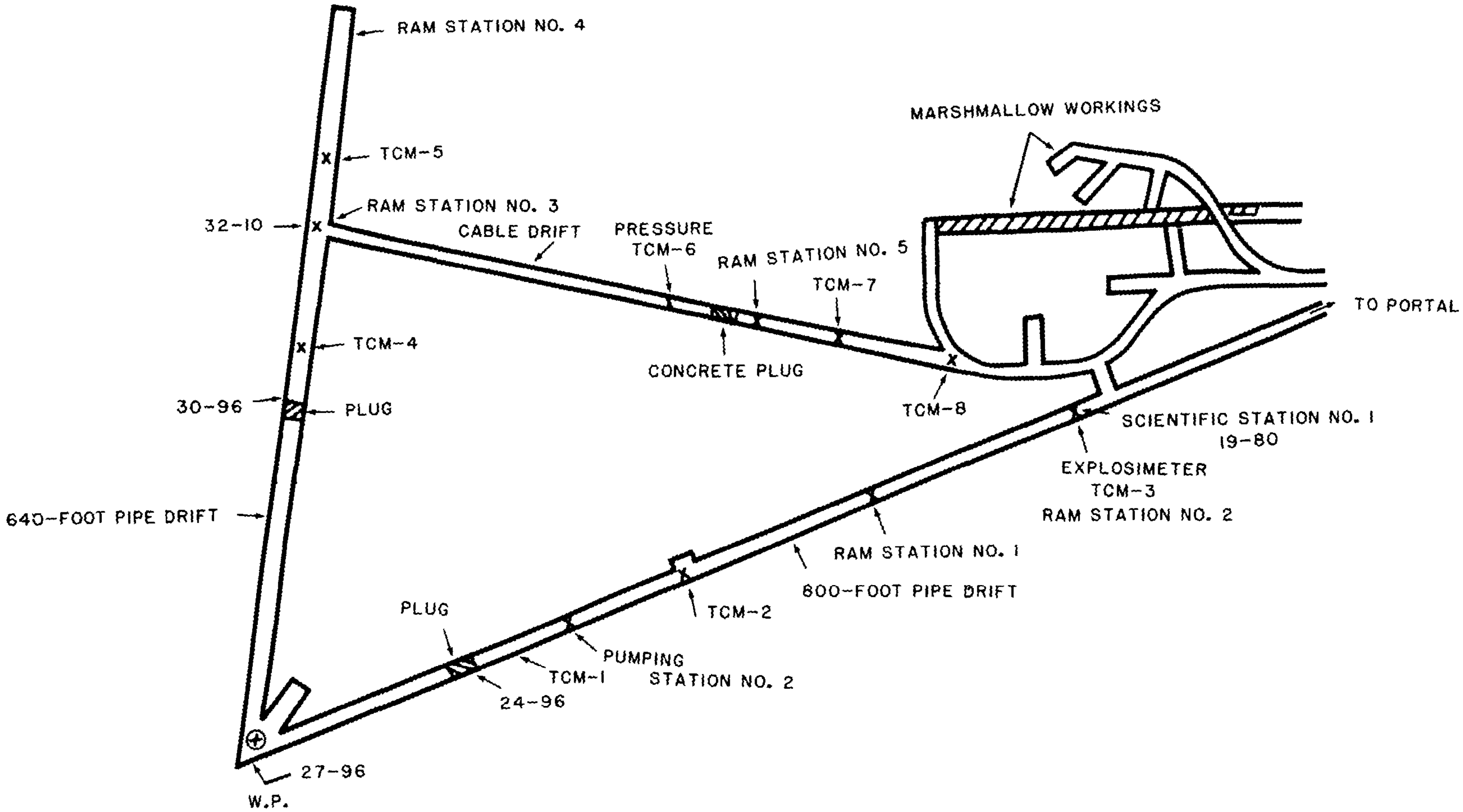

Figure 3.1 GUMDROP Tunnel

Six geophones, Texas Instrument Type S-36 with a natural period of 2 cps, were used to monitor postevent earth disturbances, cavity collapse in particular. Two geophones were placed in the portal area. Each phone required a hole 12 inches in diameter, 4 feet deep, and backfilled with tamped sand after geophone emplacement.

Signals from the geophones were sent to the monitor trailer at the FCP, by four-conductor-shielded wire to the geophone transmitter truck in the portal parking area, via microwave link to Area 3, and then by eventual retransmission to CP-1.

At the monitor trailer, the multiplexed signal was placed on magnetic tape for future reference, and then routed to four discriminators which converted the FM signal back to four analog signals representing the four geophones. Visual readout at the FCP was provided by Sanborn two-channel Model 320 recorders.

B. Tunnel Environmental Conditions

Two 3/8-inch-diameter copper tubing gas sampling lines were installed, one from Scientific Station No. 1 to the reentry safety trailer at the portal parking area, and one from inside the main blast door to the reentry safety trailer. The routing of the sampling tubes was with the scientific cables in hangers on the tunnel wall. Particular attention was given to the routing around the blast door to insure freedom from kinks or tubing collapse. During installation of the tubing, care was taken to insure that the line was kept clean and free from foreign material of any kind.

Each sampling line required a 120-volt AC normally-closed solenoid valve outside the main blast door. Each line required an off-line 0 to 10 psi pressure gauge with valve and an additional valve terminating the line at the reentry safety trailer. The installed tubing system was pressure-tested for 24 hours at 200 psi with a permissible drop in 24 hours of not more than 20 psi. Following the satisfactory pressure test, the tubing was cleaned with chlorothene.

Two additional gas sampling lines allowed sampling gases from the portal ventilation vent pipes. These two auxiliary copper tubes were run from the portal vent pipes to the reentry safety trailer for sampling at the trailer. The auxiliary lines were not needed for sampling at the portal itself because a short branch from each main vent line was located at the portal, near ground level, and provided with a closing valve.

Explosive gas mixture analyzers were placed at Scientific Station No. 1 and inside the main blast door. The readouts were at the reentry safety trailer.

Pressure transducers were located inside the main blast door and inside the cement plug in the cable drift. Temperature was measured at Scientific Station No. 1. All of these readouts were at the reentry safety trailer at the FCP.

Tunnel exhaust ventilation was passed through two charcoal filters and finally an absolute filter. Positive displacement blowers were used to overcome the large line resistance of the tunnel ventilation lines.

C. Telemetry, Air Sampling, and Radiological Safety Support

Detailed reentry plans were submitted to participating agencies prior to the test event. Test area maps with appropriate reference points were prepared. Reference markers, radiation decay recorders, and air sampling equipment were positioned in the test area. Reentry routes into the test area were established during "dry runs." Radiation monitors were briefed regarding surface reentry, sample recovery, manned stations, and security station requirements.

Thirty-five telemetry stations were in operation; 9 inside the tunnel and 26 on the surface (Table 8.1). All detectors in the tunnel were housed in explosion-proof steel boxes and were encased in foam jackets to provide shock mitigation. These units each used a pair of signal wires to conduct the signal to the reentry safety trailer located at the FCP. The surface locations were chosen with a consideration for weather conditions required at zero time and by terrain features. RAMS units were to detect airborne radioactivity and fallout in case of venting. Readings were needed both for purposes of reentry safety and documenting effluent release for Test Ban Treaty compliance.

Air sampling units were positioned at 17 surface locations. Air sampling locations were selected by an actual onsite survey with consideration given to surface meteorology and practicability of installation. Units were started and set in continuous sampling mode prior to H-3 hours by Radsafe manned station personnel.

All personnel at manned stations were provided with appropriate anticontamination clothing and equipment, and

TABLE 8.1

GUMDROP EVENT RAMS UNIT LOCATIONS

Station	Location
	UNDERGROUND
1	21+60 feet (2,160 feet from portal)
2	19+75 feet
3	32+10 feet
4	34+23 feet
5	Outside plug cable drift
6	12+00 feet
7	9+00 feet
8	Inside door 6+00 feet
9	Outside door 6+00 feet
	ABOVEGROUND
10	Portal
11	580 feet at 0° Azimuth (from SGZ)
12	585 feet at 24° Azimuth
13	275 feet at 45° Azimuth
14	322 feet at 76° Azimuth
15	713 feet at 161° Azimuth
16	402 feet at 214° Azimuth
17	464 feet at 229° Azimuth
18	498 feet at 239° Azimuth
19	155 feet at 273° Azimuth
20	265 feet at 309° Azimuth
21	480 feet at 330° Azimuth
22	584 feet at 341° Azimuth
23	1,356 feet at 12° Azimuth
24	4,013 feet at 64° Azimuth
25	943 feet at 108° Azimuth
26	923 feet at 127° Azimuth
27	986 feet at 173° Azimuth
28	1,131 feet at 239° Azimuth
29	2,230 feet at 247° Azimuth
30	1,354 feet at 267° Azimuth
31	2,600 feet at 228° Azimuth
32	Before North Vent Line Filter
33	After North Vent Line Filter
34	Before South Vent Line Filter
35	After South Vent Line Filter

Radsafe monitors were in attendance.

Radsafe provided monitoring teams and supervisory personnel for initial surface radiation surveys, aerial surveys by helicopter, and tunnel reentry parties. Radsafe personnel were stationed at the DOD Test Group Director's FCP to perform initial and subsequent ground surveys as required; provide emergency rescue and support as directed; provide and issue anticontamination equipment, portable instruments, and dosimetric devices; perform personnel, equipment, and vehicle decontamination; and operate a sample return station.

Anticontamination equipment and materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

D. Security Coverage

A muster station was established on the Pole Line Road approximately 1-1/2 miles east of U16a and west of the Timing and Firing Complex on D-day. A control station was established on Area 16 Road south of the Area 16 trailer complex. About three hours prior to planned detonation, all personnel were clear of the closed area except the arming party and others who were authorized to remain in the area. From two hours before planned device detonation to 30 minutes before device detonation, USAF and security personnel in an L-20 aircraft made a final aerial sweep of the closed portion of Area 16.

E. Air Support

A U-6A aircraft was flown by a USAF pilot and two military crewmen to perform a photography mission. The DOD photo mission was flown by a Marine Corps pilot and copilot with one crewman in a UH-43D helicopter. Both aircraft had Radsafe monitors on board. The USAF L-20 and pilot were used by Security personnel to perform aerial surveys. Cloud tracking was performed by PHS personnel in two USAF C-45's and a USAF U-3A. American Aerial Survey representatives provided postevent photo coverage using a Cessna 185.

8.2.3 Late Preevent Activities

On 20 April 1965 (D-1 day), SC personnel installed and performed maintenance on instrumentation in the trailers and the trailer park area at the portal, made final adjustments on geophones located inside the main blast door and at Station 8+70, and checked instruments in the motor van located in the portal area. EG&G representatives set up recording trailers at the trailer park above the portal area, entered the tunnel to check monitoring equipment, and checked oscilloscopes and related equipment on the surface.

Personnel from SRI, LMSC, and LRL were in the area to perform calibration checks, activate equipment, and perform button up functions. DOD representatives were onsite to perform overall coordination of activities. In addition, DOD personnel conducted inspections of the tunnel, portal area, and FCP.

8.3 EVENT-DAY AND CONTINUING ACTIVITIES

The security muster station was activated at 0200 hours on event day, and at 0455 hours a security sweep of the closed area was performed. Security and USAF personnel performed an aerial sweep of the closed area at sunrise. Permission to arm the device was granted by the Test Manager and the arming party entered the area at 0620 hours. Initial radiation survey teams were at the muster station at 0645 hours. A final weather briefing for the Test Manager and Advisory Panel was conducted at 0800 hours on 21 April 1965. The test was originally scheduled for 1000 hours, but was delayed for four hours.

Required countdowns began on radio nets 1, 2, 6, and 8. At ten minutes before device detonation, the siren on the CP-1 building ran for 30 seconds, and the red lights on top of the building were turned on until after detonation.

GUMDROP zero time was 1400 hours on 21 April 1965.

A dust cloud was observed at zero time which moved on a general heading of north to northeast. Four passes by the U3a aircraft through the dust cloud between 1402 hours and 1405 hours produced background readings at 5900 feet MSL. The elevation of the U16a portal is 5430 feet MSL. At 1406 hours, a monitoring run was made directly over GZ at 6700 feet MSL with negative results. Additional passes in the vicinity of the tunnel portal produced background readings. Aerial monitoring was terminated at 1445 PST hours because of severe turbulence in the area.

Telemetry readings for zero time to 1630 hours on D-day are shown in Table 8.2. With the exception of detectors identified as RAMS Stations 1 and 2 (Figure 8.1), and inoperative Stations 3 and 4, all other radiation detectors in the tunnel and aboveground indicated preevent background readings after detonation. Station 1 read 0.200 R/h at two minutes after zero time, decreasing to 0.010 R/h at 20 minutes after device detonation. Station 2 read 0.650 R/h at two minutes after device detonation, decreas-

TABLE 8.2

GUMDROP EVENT

TELEMETRY MEASUREMENTS INSIDE OF TUNNEL
RAMS STATIONS 1, 2, & 5

TIME (PST)	21+60' 1	19+75' 2	Cable Drift 5
1402	0.200	0.650	Bkg*
1404	0.100	0.425	Bkg
1406	0.070	0.230	Bkg
1408	0.045	0.125	Bkg
1410	0.025	0.050	Bkg
1412	0.018	0.030	Bkg
1414	0.014	0.022	Bkg
1416	0.013	0.017	Bkg
1418	0.011	0.014	Bkg
1420	0.010	0.010	Bkg
1422	0.009	0.009	Bkg
1424	0.009	0.009	Bkg
1426	0.009	0.008	Bkg
1428	0.008	0.008	Bkg
1430	0.008	0.008	Bkg
1435	0.008	0.008	Bkg
1440	0.007	0.007	Bkg
1445	0.007	0.007	Bkg
1450	0.007	0.007	Bkg
1455	0.007	0.006	Bkg
1500	0.007	0.006	Bkg
1505	0.007	0.006	Bkg
1510	0.007	0.006	Bkg
1520	0.006	0.006	Bkg
1530	0.006	0.006	Bkg
1600	0.006	0.005	Bkg
1630	0.005	0.004	Bkg
1700	0.007	0.002	Bkg
1730**	0.014	0.002	Bkg
1800	0.026	0.002	Bkg
1830	0.030	0.002	Bkg
1900	0.020	0.002	Bkg
1930	0.022	0.002	Bkg
2000	0.030	0.002	Bkg
2030	0.030	0.002	Bkg
2100	0.035	0.002	Bkg
2130	0.047	0.002	0.001
2200	0.070	0.002	0.003
2230	0.100	0.004	0.006
2300	0.120	0.004	0.009
2330	0.150	0.001	0.013

*Preevent natural radiation background
**Tunnel ventilation system on

ing to 0.010 R/h after 20 minutes. This indicated some gaseous fission product activity had entered and diffused in the 800-foot pipe drift (see Figure 8.1). Detectors in the 640-foot pipe tunnel (Station 3 and Station 4) indicated a shorted condition, probably resulting from rock spallation in the cable drift inside the concrete plug. The presence of background readings from the remaining radiation detectors in the tunnel and on the surface indicated containment of radioactivity within the tunnel had been good.

Later in the day, tunnel ventilation was turned on prior to commencing tunnel reentry. As a result, some gaseous fission products present in the GUMDROP tunnel were released through the vent line filters. Telemetry readings increased when ventilation was begun. RAMS Station 1 readings peaked at 200 mR/h on 22 April at 0100 hours. Station 5, in the cable drift, read background until 1 mR/h was measured at 2130 hours on 21 April. Station 5 readings rose to 40 mR/h by 0300 hours and peaked at 48 mR/h on 22 April at 0900 hours. Apparently, negative pressure in the tunnel when the ventilation system was turned on caused additional fission product gas to seep into the tunnel. RAMS unit readings on the vent line filters reached a maximum of 15 mR/h at 2030 hours on 21 April. Two other surface RAMS stations detected the release with maximum readings of 2 mR/h at 0230 hours and 0.3 mR/h at 1300 hours on 22 April. For additional information on this controlled release, see section 8.3.4.

8.3.1 Tunnel Structural Conditions

Immediately postevent, TCM's indicated either a normal tunnel condition (TCM's 1, 2, 3, 7, 8, 9, 10), or an open line (TCM's 4, 5, 6) which gave no information about tunnel condition. Subsequent inspection confirmed that TCM's showing normal tunnel condition had not been crushed. Considerable debris had fallen on and around TCM-1 but the monitor was not damaged. The open lines for TCM's 4, 5, and 6 were attributed to rock spalling in the cable drift.

After initial zero-time signals had ceased, geophone activity was quiet until roughly H+6 minutes. For the next minute and a half, small sporadic signals were received until a large signal, indicating cavity collapse, was noted at H+7 minutes 23 seconds. At H+7 minutes 35 seconds, the last signals had died out, indicating the completion of cavity collapse.

8.3.2 Tunnel Environmental Conditions

A preprogrammed gas chromatograph was drawing samples from the two tunnel vent lines before zero time up to H-4 minutes, when sampling was interrupted by a power failure. During this sampling time only O_2, N_2 and C_2H_6 (ethane) were detected.

At one hour and 20 minutes after detonation, power was restored and sampling from inside the gas seal door and at Scientific Station No. 1 began. The first sample from Scientific Station No. 1 indicated H_2, O_2, CH_4 (methane), CO, C_2H_6, and a questionable peak between CO and C_2H_6 (possibly due to xenon). The chromatograph had not returned to operating temperature, and quantitative information was not available. The size of the peaks relative to stable size indicated the gases to be present in less than explosive concentrations.

The first sample from the blast door indicated H_2, O_2, and CH_4 present at less than LEL levels. All further samples from both sampling heads were normal. The unit was stopped at two hours and 30 minutes after zero time in preparation for the initial tunnel reentry.

Remote reading explosimeters in the tunnel indicated zero percent explosive gas mixture from times immediately postevent until completion of the initial reentry. Remote reading pressure transducers inside the concrete plug in the cable drift and inside the gas seal door indicated no change after zero time from the preevent ambient pressures.

8.3.3 Radiation Surveys and Surface Reentry

At 1440 hours, the Test Group Director released two vehicle-borne Radsafe parties, consisting of two monitors each, for the initial survey. The two parties proceeded from the FCP along Telephone Pole Road to the Area 16 main access road, and then to the tunnel portal area, surveying enroute.

Radsafe Survey Party No. 1 proceeded through the portal area to the vicinity of the portal entrance. Upon completion of the initial survey, the team continued to obtain radiation measurements at the portal entrance and locations of interest in the portal area. The team then returned to a location near the office trailer park where Radsafe Survey Party No. 1 established a temporary mobile check station for radex control of the portal area.

Radsafe Survey Party No. 2 proceeded along the route to the film instrumentation trailer park and to the postevent drill road, surveying enroute. Upon completion, Radsafe Survey Party No. 2 returned to the temporary mobile check station and stood by for further assignments.

Survey data were reported to the net 3 radio control operator when measurements were made. Plotting facilities were maintained at the FCP and at CP-1. All pertinent radex and toxicological information was plotted. Radsafe Control was located in the operations trailer at the FCP. The initial surface radiation survey began at 1444 hours and ended at 1459 hours on event day.

All initial survey measurements indicated background radiation levels.

Sufficient Radsafe personnel were standing by at the FCP to provide rescue and emergency support, and implement radiological area control as exclusion areas were established.

As soon as the initial survey was complete, the DOD Test Group Director released parties to recover critical data. Scientific experiment organizations requiring rapid reentry were:

Portal Area Film Recovery:	EG&G, LRL, SRI, SC, and LMSC
Trailer Park Film Recovery:	EG&G, SC
Tunnel Scientific Recoveries to Scientific Station No. 1:	AFWL, LMSC, SC

Surface reentry and recovery operations were accomplished without encountering any radiological or toxicological problems.

8.3.4 Controlled Radioactivity Release

At H+3.5 hours (1730 hours) a decision was made to turn on tunnel ventilation before reentring the tunnel. During controlled radioactivity release from H+3.5 hours to H+44 hours, vent line sampling data indicated that xenon-135, rubidium-88, iodine-131, iodine-133, iodine-135, and sodium-24 were detected. Other shorter-lived noble gas fission products were assumed to be present in the tunnel exhaust. There was some indication of resuspended fission products left over from the MARSHMALLOW event. Vent line radiation monitors indicated that from the beginning of ventilation to H+44 hours approximately 1,900 curies of filtered gaseous activity was released. This release estimate was computed without regard to decay from release times. By process of elimination, this gaseous activity was assumed to be primarily isotopes of xenon and krypton.

After correcting contributions of the various radionuclides for decay from their release times, the maximum amounts of iodine-131, -133, and -135 in the atmosphere at any time were, respectively, 28, 600, and 1,300 microcuries. The maximum amount of filtered gaseous activity in the atmosphere at any time was 660 curies.

8.3.5 Tunnel Reentry

Each participant in tunnel reentry operations was certified by the Bureau of Mines as having satisfactorily completed training in the use of the two-hour McCaa breathing apparatus, along with instruction in mine rescue procedures.

The initial reentry team consisted of a Chief of Party, two Radsafe monitors, a tunnel safety engineer, and the AFWL Scientific Advisor. Each member was provided with required sets of anticontamination clothing; two self-reading pocket dosimeters (0-200 mR, 0-5 R); one two-hour McCaa breathing apparatus; a Bureau of Mines approved, hat-mounted miner's light with battery pack; and an MSA-approved, explosive-proof flashlight. Members of a second team were similarly outfitted and on standby in case they were needed.

Tunnel ventilation was begun at 3 hours and 30 minutes after detonation. When cleared by the DOD Test Group Director, and when all surface recoveries were complete, the reentry team began the initial tunnel reentry. This occurred three hours and 45 minutes after device detonation. There was no change in the tunnel ventilation setup or in utilities while any teams were underground. The reentry team entered and proceeded to the blast door, continuously monitoring for radioactivity and for toxic and explosive gases.

The reentry team opened the blast door, and inspected the tunnel to Scientific Station No. 1. As the Team proceeded from the portal to Station No. 1, they checked the 80 psi gas line for integrity. Upon arrival at Station No. 1, they checked all the high-pressure nitrogen bottles for damage and adequate tie-down, and inspected the sides of the shutter closure for undetonated high explosive. They then proceeded to that part of the tunnel forward of Station No. 1. This included checking Scientific Station 24+02 (pumping station) and Station 23+79 for high-pressure gas-bottle integrity and undetonated explosive. They next searched the Cable Drift up to the plug. Radiation and toxic gas measurements made during the initial tunnel reentry are shown in Table 8.3.

After reaching the plug, team members began their exit from the tunnel, investigating all blind drifts and old MARSHMALLOW workings on the way. The team's objective was to verify that the entire portal side of the tunnel complex was free from explosive, toxic, and radioactive gases. The highest radiation and toxic gas levels noted during the entire tunnel walk-out were in the 800-foot pipe tunnel at the extreme penetration to Station 23+00. At this location, conditions of 200 mR/h, 500 ppm CO, 1,000 ppm CO_2, and zero percent LEL of explosive mixtures were noted. Five hours and 13 minutes after device detonation, the initial reentry team emerged from the portal.

Two scientific reentry teams entered the tunnel on D-day; one at five hours and 45 minutes after detonation and the other nine hours after detonation. The first team, composed of 11 key project personnel, proceeded to Station 1, recovered dosimetry, and exited the tunnel six hours and 21 minutes after zero time. The second team was composed of 16 project personnel who also

TABLE 8.3

GUMDROP EVENT

INITIAL TUNNEL REENTRY RADIATION SURVEY DATA
21 April 1965

Time	Location	Gamma Exposure Rate (mR/h)	Toxic Gas (ppm)
1748	Outside Blast Door	0.8	
1753	Inside Blast Door	0.8	
1758	Rad-Station No. 6	1.0	
1828	CR Drift No. 4	3.0	
1830	CR Drift No. 5	3.0	
1833	18+00 (Pipe Tunnel)	1.0	
1834	Station No. 1	60.0	
1835	21+00 (Pipe Tunnel)	12.0	
1837	22+00 (Pipe Tunnel)	30.0	100 CO
			1000 CO_2
1838	23+00 (Pipe Tunnel)	200.0	500 CO
			1000 CO_2

proceeded to Station 1 to attempt extensive recoveries. Technical difficulties were encountered at Station 1, and the team exited the tunnel nine hours and 53 minutes after detonation without significant recoveries being made. This was the last reentry made on D-day.

8.4 POSTEVENT ACTIVITIES

8.4.1 Experiment Recoveries

On days following D-day, the tunnel recoveries proceeded on schedule with few problems being encountered. Use of full-face masks and anticontamination clothing was required at Scientific Station No. 1 at one point because the potential for beryllium exposure existed.

Reentry and recovery from the 640-foot pipe tunnel was not urgent and was not part of the early reentry. The initial reentry team members for this tunnel also were McCaa-qualified. When samples taken through the concrete plug in the cable drift indicated that the pressure and explosive and toxic gases were at or below tolerance, the blast door was opened. The team then proceeded to check the available tunnel for explosive, toxic, and radioactive gases. At the pumping station at Scientific Station 31+73 they checked for high-pressure gas bottle hazards, and at Station 31+43 they checked for undetonated high explosives.

8.4.2 Postevent Drilling

Preparations for postevent drilling began on 27 April 1965 at a location above the tunnel complex. Three postevent holes were drilled during this operation to obtain radioactive debris samples from the cavity area. The first drill rig began drilling at 1830 hours 28 April. Drilling continued slowly until total depth of 1,378 feet was reached at 1300 hours on 2 May. Radioactivity was detected in the cellar area and on the rig platform intermittently while personnel were rigging up for core sampling operations. Personnel were issued urine kits and provided adequate anticontamination clothing and equipment. The maximum radiation reading was 9.5 R/h in contact with a core sample taken from the hole at a depth of about 1,160 feet on 3 May.

Two other core drilling operations were conducted at this site prior to program completion. The highest reading during these operations was 3 R/h on a sample taken from a depth of 1,340 feet.

8.5 RESULTS AND CONCLUSIONS

Telemetry began at zero time and was terminated at 0400 hours on 24 April 1965. The maximum telemetry reading was at underground Station 2, located at 19+75, which read 650 mR/h two minutes after device detonation. The remote reading explosimeters in the tunnel indicated zero percent explosive gas mixture from times immediately postevent until completion of the initial tunnel reentry. The initial survey maximum reading was 200 mR/h in the pipe tunnel. The maximum postevent reading not on a core sample was 4.5 mR/h on the PS-1ASS drill platform at 1800 hours on 4 May 1965. The maximum reading at contact with a core sample was 9 R/h. No alpha radiation was detected. The maximum explosive mixture reading obtained was 80 percent of the Lower Explosive Limit on 2 May 1965 in the cellar of PS-1A at 1105 hours. Maximum toxic gas levels detected underground during postevent operations were as follows:

2200 ppm CO on 6 May 1965 at blast door at 1130 hours

2.5 ppm NO_2 on 4 May 1965 in the tunnel work area at 21+00 at 1510 hours

The maximum gamma reading from a filtered effluent release was 3 mR/h at 1300 hours on 22 April in the test area. No radioactive effluent above background levels was detected onsite by ground and aerial monitoring teams, or offsite by stationary dose rate recorders, or in any environmental samples either after the detonation or during the subsequent sample recovery operations. No fresh fission products were detected in any environmental samples collected offsite throughout this period, and no prefilter air samples contained levels of gross beta activity above normal background.

Personnel exposures received during individual entries to GUMDROP radex areas from 21 April 1965 through 29 December 1965 are summarized below. Average exposures are from self-reading pocket dosimeters as recorded on Area Access Registers. Maximum exposures are from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	2,188	680	7
DOD Participants	211	50	6

With the exception of TCM's, all health and safety instrumentation operated satisfactorily. The TCM's, however, suffered from the problem that any tunnel collapse sufficient to crush the monitor cut the telemetry wires first. As a result no information on tunnel collapse was obtained. There were no unusual problems encountered on reentries that prevented scientific recoveries for health and safety reasons. The tunnel ventilation system operated as planned with the exception of dust loading problems on the charcoal filters.

CHAPTER 9

DILUTED WATERS EVENT

9.1 EVENT SUMMARY

The DILUTED WATERS event was a DOD underground detonation with a yield less than 20 kt conducted at 0930 hours PDT on 16 June 1965 at shaft site U5b in Area 5 of the NTS (Figure 9.1). The device was emplaced in a 48-inch diameter shaft at a depth of 640 feet. DILUTED WATERS was a weapons effects test that provided information on response of equipment and materials in a nuclear detonation environment. The emplacement configuration included a maximum diameter 36-inch LOS pipe to the surface. Laboratories and contractors conducted 15 DOD scientific projects to obtain the desired information.

Effluent was released beginning about one second after detonation. Dynamic venting began 21 seconds after the detonation and ceased when the subsidence crater formed about four minutes later. For additional information on this venting, refer to Section 9.3.

9.2 PREEVENT ACTIVITIES

9.2.1 Responsibilities

The DOD Test Group Director was responsible for health and safety of all participants in the test area under his control. Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Field Command, DASA, and the AEC Albuquerque Operations Office. LRL was responsible for providing

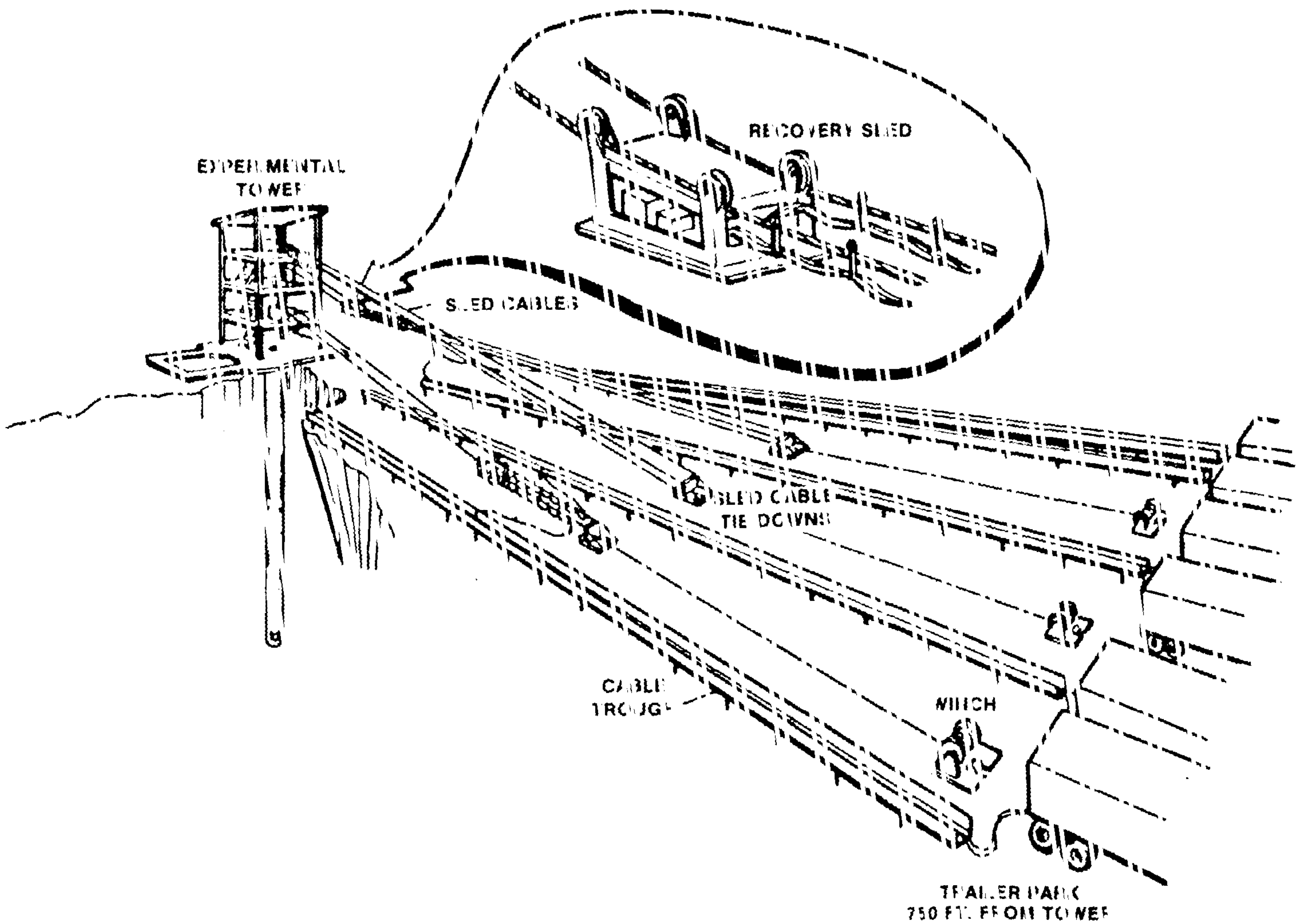

Figure 9.[illegible] DILUTED WATERS Test Configuration

and emplacing the nuclear device. Sandia Corporation was responsible for stemming and the timing and firing system. EG&G provided timing and firing circuitry and signals. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

9.2.2 Planning and Preparations

The "DILUTED WATERS Reentry Plan" described preevent preparations and postevent procedures used to conduct a safe and economical reentry within the desired time frame.

A. Radiological Safety Support

Detailed radiological safety reentry plans were submitted to participating agencies prior to the test event. Test area maps with appropriate reference points were prepared. Reference markers, radiation decay recorders, and air sampling equipment were positioned in the test area. Reentry routes into the test area were established during "dry runs." Party monitors were briefed regarding surface reentry, sample recovery, manned stations, and security station requirements.

Radsafe manned stations, Bluebird Teams, had as a primary mission documentation of any radioactive effluent released. All personnel at manned stations were provided with appropriate anticontamination clothing and equipment, and Radsafe monitors were in attendance. Radsafe monitors were stationed at all WSI security roadblocks and at all work areas within the exclusion area.

Anticontamination materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

B. Telemetry and Air Sampling Support

RAMS units were located as follows:

Station 1	- SGZ
Stations 2 through 5	- 100-foot arc at 90-degree intervals
Stations 6 through 10	- 500-foot perimeter fence at 0°, 60°, 120°, 240°, and 300°
Stations 11 through 22	- 1,000-foot arc at 30-degree intervals beginning at 15°
Stations 23 through 34	- 2,000-foot arc at 30-degree intervals beginning at 0°

Twelve air sampling units were positioned at 30-degree intervals (beginning at 30 degrees) on the 1,000-foot arc, and twelve air sampling units were positioned at 30-degree intervals (beginning at 15 degrees) on the 2,000-foot arc.

C. Security Coverage

Control of the area was maintained by the use of roadblocks, access permits, and a "Schedule of Events". Parties could enter the controlled area only with the permission of the Test Group Director or the Test Manager. WSI security personnel conducted aerial sweeps of the test area and outlying terrain on 15 June and event day.

D. Air Support

A USAF L-20 aircraft and pilot was provided to security for sweeps of the closed area on 15 and 16 June. DOD personnel used a UH-43D aircraft for their photo missions. An Air Force U-3A aircraft, manned by a pilot, co-pilot and two PHS monitors equipped with portable radiation detection instruments, tracked the effluent to assist in positioning ground monitors. Two PHS C-45 aircraft containing sampling equipment also were used as aids in cloud tracking. Their primary purpose, however, was cloud sampling to determine cloud size and inventory of radionuclides. The EG&G/NATS Martin 404 cloud tracking aircraft was available for use. Postevent photos were taken by American Aerial Services personnel in a Cessna 185 aircraft.

A PHS Twin Beechcraft flew a sampling mission and a PHS Aerocommander equipped with an experimental beta detection system flew a cloud height mission.

9.2.3 Late Preevent Activities

Insertion of the device canister and LOS pipe was begun on 13 June. By 14 June, activities appeared to be progressing on an accelerated schedule. Thus, a 16 June event date was announced with a planned execution time of 0930 hours. LOS pipe insertion was completed on 15 June with installation of the fast gate, pipe cap, and device diagnostic package. The annulus between the pipe and the hole casing was then filled with sand and the tower aligned over the LOS.

On 15 June, SC personnel set up and checked out instrumentation from the tower to Trailers L-31, B-21, B-23, B-50, B-51, and F-23 which were located approximately 750 feet east of the tower. Final adjustments were made to geophones, and telemetry equipment at SGZ was checked. SC personnel also assisted LRL personnel with electronic work for SGZ installations. LRL personnel checked equipment, participated in dry runs, and installed instruments.

USC&GS personnel installed and checked out seismic stations. Final adjustments at the trailer area and tower were made by Hughes personnel. AVCO/RAD employees performed cable checks, armed the disconnect system, checked the control system, and armed recorders. Hookup of timing signals to cables, final battery installation in a cassette at the tower, and final instrumentation checks were made by HDL representatives.

DOD personnel installed remote cameras and conducted pre-event photo coverage. Representatives from Bell Telephone Laboratories, U.S. Army Electronic Laboratory (USAEL), Naval Ordnance Lab, White Oak (NOL/WO), AFWL, and General Electric Co. (GE) made final instrumentation and calibration checks and verified proper operation of instruments and the total test system.

9.3 EVENT-DAY ACTIVITIES

Button up of the area was completed and a final dry run held just after midnight on 16 June.

At five and one-half hours before planned detonation on 16 June 1965 (D-day) LRL, SC, and EG&G personnel were at SGZ to complete preparations for the arming procedure. At this time, they activated the interconnection with diagnostics, cabling, ball valve, fast gate, and closures.

A DOD party was at the trailer park and SGZ area at this time to observe final event preparations. A final visual check was made at the test tower. Simultaneously, the preparations listed in Table 9.1 were occurring. At sunrise, security personnel conducted a sweep of the closed area.

Approximately three hours before scheduled zero time, DOD photo parties proceeded to the primary station 10,000 feet south of SGZ to establish a manned photo station. One party was to take still photos at zero time and the other would provide motion picture coverage. A DOD aerial photo party was in the area 45 minutes before scheduled device detonation.

The final weather briefing for the Test Manager and his Advisory Panel was conducted about two and one-half hours prior to scheduled device detonation.

Permission to arm was given at 0715 and the arming party was out of the closed area at 0800. Both Radsafe initial survey teams were at the muster station at 0850 hours.

Required countdowns began at 0900 on radio nets 1, 2, 6, and 8. Ten minutes before detonation the siren on Building CP-1 ran for 30 seconds, and the red lights on top of the building were turned on until after the detonation.

DILUTED WATERS zero time was 0930 hours on 16 June 1965.

Immediately after zero time a flash of light appeared at the top of the LOS pipe, and luminous, burning gas engulfed the lower portion of the tower. The flash lasted for about one second and was followed by the release of a red-brown cloud. This release decreased in intensity and almost completely stopped after 15 to 20 seconds.

At 21 seconds after zero time, clouds of light brown gas forcefully emanated from the area under the tower. RAMS unit

TABLE 9.1

EVENT-DAY PREEVENT EXPERIMENT PREPARATIONS

Experiment Agency	Activity
General Atomic	1. Loaded oscilloscope cameras and tape recorders 2. Set station programmer 3. Final button up preparations
AFWL	1. Final operational check 2. Final inspection of cabling to tower 3. Button up at AFWL Trailer
HDL	1. Final operational check 2. Final inspection of cabling to tower 3. Button up at HDL Trailer
LRL	1. In Diagnostic Trailer Compound and at SGZ for final film loading and checkout of equipment.
USC&GS	1. Final adjustment to seismic stations

readings at SGZ, 100 feet northeast, and 100 feet northwest were greater than 10,000 R/h at one minute after zero time. This second and stronger release continued until surface subsidence occurred four minutes and 12 seconds after the event. Subsidence completely stemmed the release and produced a crater approximately 417 feet in diameter at the surface and about 97 feet deep in the center. Soon thereafter, remote readings of radioactivity on the surface showed a decrease, and continued to decline with time. Readings received from the radiation detection units placed on the 500-foot perimeter decreased from a high of 180 R/h due north from SGZ. Other 500-foot and more distant units had lower initial readings than 180 R/h, and these readings decreased steadily with time.

In addition to the venting of radioactive material, a second problem occurred. The power monitors for the three sled recovery winches indicated a power loss between zero and H+1 second. In spite of this indication, the winches were manually actuated as planned, starting at H+60 seconds. However, the monitors were accurate, and the winches did not start due to the power failure. Thus, the experiment sleds remained on the tower, and during cavity collapse fell with the tower into the bottom of the crater.

Since surface winds at detonation time were from the south, effluent was not blown directly over the trailer park. However, due to low wind speed (6 mph) effluent remained in the area long enough for gamma shine from the cloud to cause a significant radiation exposure to the trailers; and, more importantly, to the oscilloscope film.

9.3.1 Cloud Tracking and Monitoring

The cloud traveled northeast at about 5 to 8 miles per hour and reached a height of about 2,500 feet above the surface by one hour after detonation. Radiation intensity at the leading edge of the cloud was 10 mR/h at that time. Winds in the area were light and variable, and released effluent remained within ten miles of SGZ for more than an hour. Penetration into the offsite area did not occur until about 1530 hours, at which time the remaining effluent was moving slowly toward the northeast.

Ground monitors were operating along Highway 25 from Hiko Junction, Nevada, to just southeast of Queen City Summit, Nevada. Two monitors were located in Penoyer Valley, about ten miles due south of Queen City Summit. When no readings above background were observed by 1500 hours, ground monitors moved back to the test range complex. At 1530 hours, ground monitors encountered effluent along the northeastern boundaries of the test range complex. Two readings of 0.02 mR/h (gamma) were observed. Because low radiation levels were encountered, ground monitors were directed to terminate the mission.

By nine hours after detonation, the cloud was approximately 40 miles north-northeast of the test range complex and over an unpopulated area. The cloud had dispersed to an irregular rectangular shape about 35 miles long (north to south) and 20 miles wide (east to west). The readings at the edge of the cloud had dropped to just slightly above background.

According to the PHS, no offsite exposure rate recorder activity or film badge exposures could be attributed to this event, and no health problems or violations of the Limited Test Ban Treaty occurred as a result of the release.

9.3.2 Test Area Monitoring

At 0930 the DOD photo party left their manned station prior to cloud arrival and proceeded directly to the FCP arriving there at 0946. No readings above background were recorded at the photo station while personnel were located there.

Bluebird Team No. 1 approached the cloud path at 0950 hours for the first survey of the 5H Road running from Radsafe Stake 5H8 (1.75 miles southeast of SGZ) to Stake 5H30 (4.5 miles northeast of SGZ). This survey was complete at 1030 hours, with a maximum reading of 400 mR/h at Stake 5H14 (1 mile northeast of SGZ) at 0959 hours. At 1030 hours, Team No. 1 made a reverse survey of the 5H Road from Stake 5H30 to Stake 5H6 (1.5 miles southeast of SGZ), completing this survey at 1046 hours. The maximum reading was 325 mR/h at Stake 5H14 at 1041 hours. A third and final survey was made by Team No. 1 beginning at 1124 hours and finishing at 1151 hours. Surveys were conducted from Radsafe Stake 5A16 (2.5 miles south of SGZ) to 5H18 (1.75 miles northeast of SGZ) with a maximum reading of 110 mR/h at Stake 5H14.

Bluebird Team No. 2 approached the cloud path at 1015 hours, conducted an extensive survey and was back out of the area by 1303 hours. A maximum reading of 150 mR/h was encountered at Stake 5T9 at 1021 hours.

The initial surface radiation survey began at 1030 hours on 16 June 1965 and was completed at 1255 hours on the same day. Table 9.2 shows these data.

Two vehicle-borne Radsafe parties, consisting of two monitors each, performed the initial survey of the immediate test area. They were referred to as Radsafe Survey Team No. 1 and Radsafe Survey Team No. 2. When released by the Test Group Director, Survey Team No. 1 proceeded from the FCP north on the 5A road to Well 5B, then north on the 5J road to the U5b main access road. The team then traveled east on the main access road to survey the perimeter fence and other locations of interest. Upon

TABLE 9.2

DILUTED WATERS EVENT

INITIAL RADIATION SURVEY DATA
16 June 1965

Time	Location (from SGZ)	Gamma Exposure Rate (mR/h)
1030	Radsafe road stake 5A30 (7 miles S)	Bkg*
1035	Radsafe road stake 5A15 (2-1/4 miles S)	2
1036	Well 5B	8
1038	Radsafe road stake 5G2 (3/4-mile S)	35
1040	Radsafe road stake 5G4 (1/2-mile S)	120
1041	West perimeter fence	2,000
1044	100 feet from north perimeter fence	1,200
1046	South perimeter fence	2,500
1130	Radsafe road stake 5C3 (1-1/4 miles SW)	10
1140	Radsafe road stake 5C6 (1-1/4 miles W)	10
1200	2 miles east of Radsafe road stake 5D10	10
1205	1 mile south of Radsafe road stake 5J7	100
1218	10 feet south of crater lip	1,000
1220	South crater lip	1,500
1255	2,300 feet north of SGZ	100

*Background radiation level

completion of this survey, and at the direction of Radsafe Control, Team No. 1 went to the trailer park area to assist recovery operations at that point. Survey Team No. 2 proceeded from the FCP north on the 5A road to Well 5B. Then Team No. 2 proceeded northeast on the 5G road to the trailer park where monitors surveyed the trailer park area and stood by for recovery operations.

Each survey team reported measurements and locations via net 3 radio enroute. Plotting facilites were maintained at the FCP and CP-1. All pertinent radex area and toxicological information was recorded.

Sufficient Radsafe personnel were standing by at the FCP to provide rescue and emergency support, if needed, and implement radiological area control when exclusion areas were established.

Each area and all contaminated or radioactive materials were marked to indicate radiation levels. Personnel entering radiation areas or working with contaminated material were briefed concerning potential exposure and safety precautions, and were provided with anticontamination clothing, equipment, and materials.

Decontamination units were positioned at entrances to controlled areas. Personnel and equipment were monitored and decontaminated as necessary. Drill rigs and associated equipment used in postevent activities also were monitored and decontaminated as necessary.

9.3.3 Reentry Activities

At early times, radiation readings in the trailer park were too high to permit data recovery. Initial reentry parties were allowed into the area to recover radiation sensitive data films starting about 1130 hours. All film was recovered as soon as practical after that time.

Most of the oscilloscope photographs were made using Polaroid film. The first few films to be developed during recovery of data from the trailers showed no traces on the prints. Thus, remaining data was recovered by removing camera backs from the scopes without developing the film.

By 1530 hours most of the magnetic tape also had been recovered from the trailer park. Initial estimates based on limited dosimetry in the trailers were that total data record exposures of from 2-8 R were experienced prior to film recovery, depending on exact trailer location and trailer shell construction. All personnel entering radex areas were issued pocket dosimeters and were dressed in anticontamination clothing. The maximum personnel exposure during recovery, as indicated by pocket dosimeter readings, was 125 mR, and the next two highest exposures were 100 mR.

Experimenting organizations having data or experiments to be recovered were Lookout Mountain Air Force Station (LMAFS), HDL, GE, AFWL, GA, LRL, SC, NOL/WO, USAEL, EG&G, Hughes, BTL, AVCO/RAD and USC&GS in addition to DOD. A party from AAS made a postevent aerial survey of the SGZ area.

Radiation monitors entered the crater late on D-day and found significant amounts of alpha contamination. This contamination was produced by physical damage to several fission-foil neutron threshold detectors which resulted in scattering small amounts of plutonium. Visual observation indicated that sleds on the second and third floors were undamaged and near their preevent positions on the tower. The first floor of the tower was partially covered with earth, and it appeared that the first floor sled had been damaged considerably.

9.4 POSTEVENT ACTIVITIES

9.4.1 Experiment Recovery

While no trailers (including the two located forward of the trailer park) experienced any damage from ground shock, the trailer park had become contaminated by fallout. Thus, it was impractical for experimenters to remain there long enough to play back tapes in the trailers. On 17 June, day crews moved trailers to an uncontaminated location about one-half mile from the trailer park. The trailers were decontaminated, power supplied to them, and experimenters were allowed to start preliminary data analyses. A double hot line was set up at the request of the SC health physicist, and a decontamination area was roped off for those personnel involved in crater recovery work.

By the morning of 18 June, the second and third floor sleds were removed by crane from the crater. Late on 18 June those items which could easily be retrieved from the first floor sled were brought to the lip of the crater. Project experiment recovery was performed at this location.

9.4.2 Postevent Drilling and Mining

Postevent drilling began on 23 June 1965 at 1000 hours. One postevent hole and two sidetrack holes were drilled. Initial core sampling began at 1525 hours and was complete at 1900 hours the same day. Nineteen core samples were extracted. Drilling on the first sidetrack began at a depth of 446 feet on 24 June at 2100 hours. Core sampling started at 0505 hours on 25 June and was completed at 0936 hours, with a total of thirty core samples taken. The second sidetrack began on 25 June 1965 at 1150 hours. Drilling started at 531 feet. Twelve core samples were extracted between 1710 and 2000 hours, and the abandonment valve was closed at 2210 hours on 25 June.

Mining at SGZ commenced 15 November 1965 as part of an investigation to determine cause of venting. Mining operations were completed 22 February 1966.

9.4.3 Industrial Safety

Checks were made on each shift for toxic gases and explosive mixtures. These measurements were recorded in the monitor's log book. All personnel entering the shaft were required to wear full radex clothing with supplied-air respirators. Continuous ventilation was supplied when personnel were working in the shaft. The ventilation exhaust line was monitored for CO. Industrial safety codes, including specific codes for drilling, were established by REECo and were emphasized during all operations.

9.5 RESULTS AND CONCLUSIONS

Telemetry coverage began at zero time on 16 June and continued until 1400 hours on 7 July 1965. The maximum telemetry readings were greater than 1,000 R/h at SGZ, 100 feet northeast, and 100 feet northwest at one minute after device detonation. The maximum initial survey reading was 2.5 R/h at the south edge of the perimeter fence. This reading was recorded at 1046 hours on 16 June 1965. The highest alpha radiation reading was greater than 100,000 $c/m/55cm^2$ in the crater.

During postevent drilling operations, a maximum reading of 1.5 mR/h was recorded at the drilling platform on 23 June 1965. Tests were run for toxic gases and explosive mixtures; however, none were detected.

Personnel exposures received during individual entries to DILUTED WATERS radex areas from 16 June 1965 through 22 February 1966, are summarized below. Average exposures are from self-reading pocket dosimeters as recorded on Area Access Registers. Maximum exposures are from film dosimeter records.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	4,119	1,295	16
DOD Participants	246	755	30

The DILUTED WATERS event resulted in deposition of minor amounts of radioactivity in the offsite populated area to the northeast of the test range complex. The exact contribution of radioiodines from this event, if any, to milk supplies was not known due to existing radioiodine from previous nuclear testing on the Chinese mainland and the testing of a nuclear rocket engine at the Nuclear Rocket Development Station (NRDS). Radioiodine entered milk supplies through fallout on feed for dairy cattle. Radioiodines present in milk sampled by the PHS were well below accepted safety levels established by the AEC. According to the PHS, there appeared to be no health problems and no treaty violation associated with release of radioactivity after the DILUTED WATERS event.

Shortly after DILUTED WATERS, an ad hoc committee was established to determine the cause of the radioactive release and to make recommendations for avoiding releases from future events of this type. This committee included representatives from LRL, LASL, SC, AEC/NVOO and the DOD. At the request of this ad hoc committee, recovery of data was accomplished in two phases.

Phase I was a preliminary investigation of the SGZ area to obtain and evaluate immediately available data, and to determine methods of recovery which would best yield meaningful data in the most expedient manner. This preliminary phase began on 22 June 1965 with completion of experimental sled recovery by DOD. Radsafe parties made gamma and alpha surveys of the SGZ and tower areas. DOD, SC, and EG&G still photography groups covered post-event damage to the SGZ area prior to any material removal. Clearing of the SGZ area which allowed access to the pad was completed the week of 28 June 1965. The fast gate was recovered the week of 28 June 1965. Photos and deposited material samples were taken throughout the recovery operation until completion of Phase I.

Phase II began on 1 September 1965 and was conducted to determine failure modes below SGZ to the depths of the ball valves, if necessary. Surface installations and preparation for mining were completed on 27 September. However, rain and labor problems delayed the start of mining operations until 15 November 1965.

The general conclusions of the ad hoc committee were that the device was buried too shallowly for its actual yield and the design of the LOS pipe and closure system was marginal.

CHAPTER 10

TINY TOT EVENT

10.1 EVENT SUMMARY

The TINY TOT event was a DOD underground detonation with a yield less than 20 kt conducted at 1000 hours PDT on 17 June 1965 at tunnel site U15e in Area 15 of the NTS. The device was emplaced in granite on the flat surface of a hemispherical cavity approximately 40 feet in radius at the end of a 200-foot-long tunnel from a 364-foot deep shaft (Figure 10.1). This event was a weapons effects test designed to obtain information on transmission of ground shock, and represented the first known nuclear detonation event conducted on a rock surface within an underground cavity. Laboratories and contractors conducted six DOD scientific projects to obtain desired information. No surface collapse was predicted and none occurred. There was minor leakage of radioactive noble gases along multiconductor cables into the access tunnel and out into the atmosphere. This release was not detected outside the boundaries of the NTS.

10.2 PREEVENT ACTIVITIES

10.2.1 Responsibilities

The DOD Test Group Director was responsible for safe conduct of all TINY TOT project activities in Area 15. This included responsibility for health and safety of all participants in the test area under his control. Procedures for radiation exposure and contamination control in this area were in accordance with requirements of the DOD Test Group Director or his representative. These procedures included use of telemetered

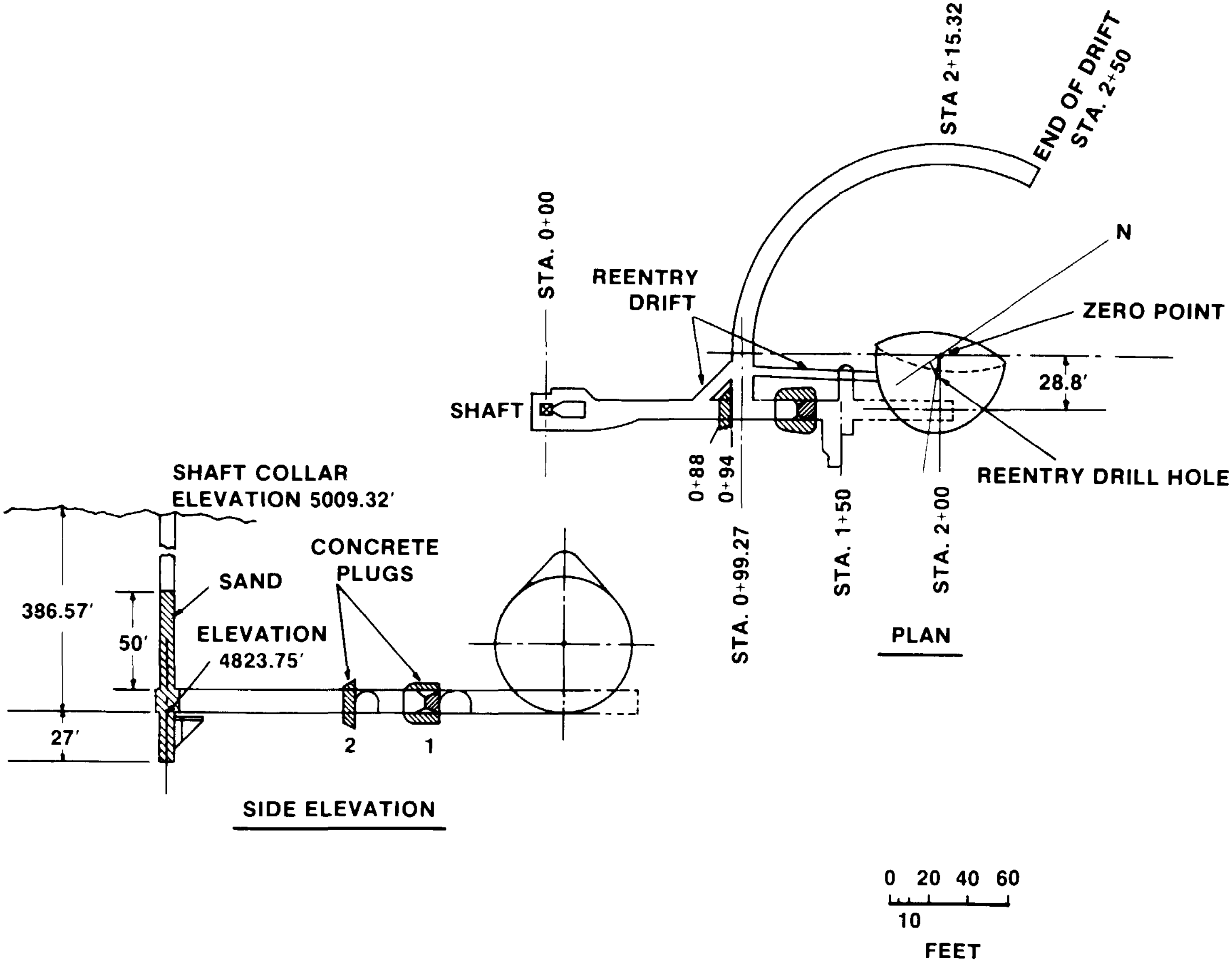

Figure 10.1 Plan and Elevation of TINY TOT Excavations

radiation measurements, air sampling, film badges, and monitors. Responsibilities of AEC and AEC contractor personnel were in accordance with established AEC/DOD agreements or were the subject of separate action between Field Command, DASA, and the AEC Albuquerque Operations Office. Sandia Corporation was responsible for timing and firing systems, and EG&G personnel were responsible for arming and firing the device. The DOD was responsible for preevent installation and postevent removal of equipment necessary for its project activities.

10.2.2 Planning and Preparations

The "TINY TOT Reentry Plan" described preevent preparations and postevent procedures used to conduct safe and economical reentry within the desired time frame. Stemming design incorporated necessary provisions to maximize safety of reentry.

A. Radiological Safety Support

Detailed radiological safety reentry plans were submitted to participating agencies prior to the test event. Test area maps with appropriate reference points were prepared. Reference markers, radiation decay recorders and air sampling equipment were positioned in the test area. Reentry routes into the test area were established during "dry runs." Party monitors were briefed regarding surface reentry, sample recovery, manned stations, and security station requirements.

RAMS units were positioned as follows:

- Station 1: 50 feet from end of instrument drift
- Station 2: Intersection of instrument drift and main drift
- Station 3: 10 feet outside blast door

Station 4: 50 feet outside blast door
Station 5: Top of sand plug
Station 6: U15e shaft collar
Station 7: U15e SGZ
Station 8: SRI trailer park
Station 9: Sandia trailer park
Station 10: Station 1500 shaft collar (HARD HAT)
Stations 11 through 22: 30-degree intervals on the 400-foot arc
Stations 23 through 34: 30-degree intervals on the 1,000-foot arc

The RAMS readout was at the DOD Test Group Director's FCP, and all readings were to be reported via net 3 radio. Plotting facilities were maintained at the FCP and CP-1. All pertinent radex area and toxicological information was to be plotted.

Radsafe coordinated with DOD Health and Safety representatives requirements for monitoring and equipment support and air sampling and telemetry arrays, including estimates of time in position and location. Radsafe monitors were to be stationed at WSI security roadblocks and at all work areas within the exclusion area to perform surveys and provide other support as directed. All personnel at manned stations were provided with anticontamination clothing and equipment, and Radsafe monitors were in attendance.

Monitoring teams and supervisory personnel were provided for initial surface radiation surveys, aerial surveys by helicopter, and tunnel reentry parties. Radsafe personnel were standing by at the FCP prior to detonation to perform surveys and to provide emergency support as directed; to provide and issue anticontamination equipment, portable radiation detection instruments, and self-reading dosimeters; to operate area control check stations; and to perform personnel, equipment, and vehicle decontamination as required.

Anticontamination materials available included coveralls, head covers, shoe covers, full-face masks, supplied-air breathing apparatus, plastic suits, gloves, plastic bags, and masking tape.

The "TINY TOT Reentry Plan" was prepared for use by all event-associated personnel. In addition Radsafe personnel were provided with Detailed Initial Reentry Procedures for both surface and tunnel reentries.

B. Security Coverage

Approximately seven and one-half hours before planned device detonation, the muster station was established on the Area 10 Circle Road west of the Area 15 access road intersection. A control station was established at the north junction of the Area 10 Circle Road and Mercury Highway. Areas 8 and 15 were to be closed and controlled until declared open by the Test Manager, and a screening station was established on the Area 10 Circle Road at the junction of the access road to Sedan Crater.

All other roads into the closed area were secured. An Observer Area was established on the T2c access road at the junction of the Area 10 Circle Road.

C. Air Support

An EG&G/NATS Martin 404 aircraft flew a preevent tracking mission over the event area, then returned to McCarran Airport (located in Las Vegas) on standby. Thirty minutes before detonation, Air Force and PHS personnel in a U-3A and two C-45 aircraft orbited outside the closed area to be available for cloud tracking. DOD personnel in a Marine Corps UH-43D helicopter and LMAFS personnel in a USAF U-6A performed photography missions.

10.3 EVENT-DAY ACTIVITIES

A sweep of the closed area was begun approximately five hours before detonation. Personnel not associated with the event were advised that they must be clear of the area by four hours before device detonation. At that time, an aerial sweep of the closed and surrounding area was conducted by Air Force and security personnel in an L-20 aircraft. By three hours before detonation, all personnel except those authorized were out of the controlled area. Personnel leaving the closed area exited through the muster or control stations.

A count of all muster-badged personnel remaining in the area was conducted two and one-half hours prior to detonation and reported to the Test Manager through the Operations Coordination Center. A final sweep and clearance operation was conducted in order that permission to arm could be granted.

The final weather briefing for the Test Manager and Advisory Panel was conducted two hours prior to planned detonation on 17 June 1965. Participating organizations (SRI, BRL, SC, and DOD) had conducted final instrument checks and performed button up activities before departing the area. At 0710 hours, permission to arm the device was requested and received from the Test

Manager. The arming party entered the closed area at 0720 and exited at 0825.

Required countdowns began at 0930 on radio nets 1, 2, 6, and 8. Ten minutes before detonation the siren on the CP-1 building ran for 30 seconds, and the red lights on top of the building were turned on until after the detonation.

TINY TOT zero time was 1000 hours on 17 June 1965.

10.3.1 Telemetry Measurements

Telemetry coverage began at zero time. Readings from underground Stations 1 through 5 and surface Stations 6 and 7 during the first day are shown in Table 10.1. Radiation readings were background at Stations 8 through 20 and 22 through 34 from zero time until readings were discontinued at 0800 hours on 18 June 1965. Station 21 indicated readings of 0.5 mR/h to 3 mR/h from nine minutes to 27 minutes after zero time, and read background the rest of the time. Readouts of U15e shaft collar and SGZ units were terminated when initial survey monitors reached the shaft collar.

10.3.2 Radiation Surveys

Two vehicle-borne Radsafe parties, consisting of two monitors each performed the initial radiation survey. They were referred to as Radsafe Survey Team No. 1 and Radsafe Survey Team No. 2. When released by the Test Group Director, the two parties proceeded from the FCP along the Area 15 main access road and then to the shaft area surveying enroute. Survey data were reported via net 3 radio when measurements were made (Table 10.2). Plotting facilities were maintained at the FCP and CP-1. All pertinent radiation exposure data and toxicological information were plotted.

Table 10.1

TINY TOT EVENT

TELEMETRY MEASUREMENTS UNDERGROUND
(Gamma Radiation in R/h)

TIME (PST)	50' FROM END OF INSTRUMENT DRIFT	INTERSECTION OF INSTRUMENT DRIFT AND MAIN DRIFT	10' OUTSIDE BLAST DOOR MAIN DRIFT	50' OUTSIDE BLAST DOOR MAIN DRIFT	TOP OF SAND PLUG MAIN DRIFT	U15e SHAFT COLLAR	U15e SGZ
1001	10.00	200.00	Neg.	0.70	0.40	Bkg	Bkg
1002	40.00	700.00	0.60	12.00	0.90	0.040	Bkg
1003	50.00	800.00	0.60	10.00	15.00	0.100	Bkg
1004	175.00	1000.00	0.70	10.00	15.00	0.125	Bkg
1005	250.00	>1000.00	0.80	8.00	13.00	0.125	Bkg
1008	450.00	>1000.00	1.00	7.00	12.00	0.110	Bkg
1009	500.00	>1000.00	1.50	7.00	11.00	0.400	0.0005
1010	700.00	>1000.00	2.50	6.00	10.00	0.700	0.0005
1011	700.00	>1000.00	3.00	6.00	9.00	0.700	0.001
1013	700.00	>1000.00	3.50	6.50	8.00	0.700	0.001
1015	700.00	>1000.00	4.50	7.00	7.50	0.750	0.001
1016	700.00	>1000.00	5.50	9.00	7.00	0.600	0.003
1017	700.00	>1000.00	6.00	10.00	7.00	0.600	0.003
1019	750.00	>1000.00	7.00	12.00	6.00	0.650	0.0025
1021	750.00	>1000.00	9.00	15.00	6.00	0.500	0.0025
1023	800.00	>1000.00	10.00	18.00	5.50	0.700	0.0025
1025	800.00	>1000.00	12.00	21.00	5.00	0.500	0.002
1027	800.00	>1000.00	13.00	25.00	5.00	0.450	0.0025
1029	850.00	>1000.00	15.00	27.00	5.00	0.450	0.003
1031	800.00	>1000.00	18.00	30.00	5.00	0.450	0.002
1033	800.00	>1000.00	18.00	31.00	5.00	0.400	0.002
1035	800.00	>1000.00	20.00	40.00	5.00	0.400	0.002
1037	800.00	>1000.00	22.00	40.00	4.50	0.400	0.002
1039	800.00	>1000.00	25.00	45.00	5.00	0.400	0.002
1041	800.00	>1000.00	25.00	50.00	7.00	0.350	0.0015

Table 10.1 (Continued)

TIME (PST)	50' FROM END OF INSTRUMENT DRIFT	INTERSECTION OF INSTRUMENT DRIFT AND MAIN DRIFT	10' OUTSIDE BLAST DOOR MAIN DRIFT	50' OUTSIDE BLAST DOOR MAIN DRIFT	TOP OF SAND PLUG MAIN DRIFT	U15e SHAFT COLLAR	U15e SGZ
1044	800.00	>1000.00	38.00	55.00	8.00	0.300	0.001
1047	850.00	>1000.00	30.00	60.00	7.00	0.325	0.0015
1050	900.00	>1000.00	35.00	70.00	10.00	0.275	0.001
1053	900.00	>1000.00	40.00	70.00	12.00	0.300	0.001
1056	950.00	>1000.00	40.00	75.00	15.00	0.250	0.001
1059	1000.00	>1000.00	45.00	80.00	15.00	0.250	0.001
1102	1000.00	>1000.00	45.00	80.00	18.00	0.240	0.0007
1105	1000.00	>1000.00	46.00	85.00	20.00	0.225	0.00075
1108	1000.00	>1000.00	50.00	90.00	20.00	0.210	0.0005
1111	950.00	>1000.00	50.00	90.00	18.00	0.200	Bkg
1114	900.00	>1000.00	50.00	90.00	20.00	0.200	0.0005
1117	900.00	>1000.00	50.00	90.00	20.00	0.190	0.0005
1120	900.00	>1000.00	50.00	90.00	24.00	0.180	0.0005
1123	880.00	>1000.00	50.00	95.00	32.00	0.160	0.0005
1126	850.00	>1000.00	52.00	100.00	38.00	0.160	Bkg
1129	800.00	>1000.00	55.00	100.00	40.00	0.150	Bkg
1132	800.00	>1000.00	55.00	100.00	38.00	0.150	---
1135	800.00	>1000.00	55.00	100.00	57.00	0.150	Bkg
1145	750.00	>1000.00	57.00	100.00	40.00	0.120	Bkg
1155	700.00	1000.00	60.00	105.00	35.00	0.110	Bkg
1205	600.00	950.00	60.00	110.00	55.00		
1215	700.00	900.00	60.00	110.00	55.00		
1225	580.00	800.00	60.00	105.00	60.00		
1235	650.00	700.00	60.00	110.00	85.00		
1245	500.00	650.00	60.00	110.00	80.00		
1255	480.00	600.00	60.00	110.00	80.00		
1305	450.00	590.00	60.00	110.00	70.00		
1315	410.00	510.00	60.00	105.00	90.00		
1325	400.00	500.00	60.00	110.00	95.00		
1335	390.00	500.00	60.00	105.00	110.00		

Table 10.1 (Continued)

TIME (PST)	50' FROM END OF INSTRUMENT DRIFT	INTERSECTION OF INSTRUMENT DRIFT AND MAIN DRIFT	10' OUTSIDE BLAST DOOR MAIN DRIFT	50' OUTSIDE BLAST DOOR MAIN DRIFT	TOP OF SAND PLUG MAIN DRIFT
1345	450.00	460.00	59.00	105.00	110.00
1355	320.00	440.00	59.00	105.00	110.00
1405	300.00	410.00	59.00	100.00	105.00
1415	300.00	400.00	59.00	100.00	105.00
1425	290.00	400.00	59.00	100.00	100.00
1435	260.00	350.00	54.00	100.00	90.00
1445	230.00	310.00	55.00	95.00	90.00
1455	250.00	300.00	55.00	95.00	85.00
1505	250.00	300.00	52.00	95.00	89.00
1515	230.00	290.00	52.00	90.00	90.00
1525	220.00	280.00	51.00	90.00	90.00
1540	205.00	260.00	50.00	90.00	82.00
1555	200.00	260.00	50.00	90.00	60.00
1610	170.00	250.00	45.00	7.00	60.00
1630	160.00	220.00	42.00	3.00	25.00
1645	150.00	200.00	30.00	2.50	13.00
1700	150.00	200.00	12.00	2.20	10.00
1715	130.00	180.00	7.00	1.70	16.00
1730	120.00	180.00	7.00	1.50	15.00
1745	120.00	160.00	5.00	1.40	11.00
1800	110.00	160.00	5.00	1.30	9.00
1815	100.00	145.00	8.00	1.10	10.00
1830	100.00	140.00	7.00	1.00	10.00
1845	95.00	130.00	5.00	0.9	10.00
1900	90.00	110.00	3.50	0.9	8.00
1915	87.00	110.00	3.00	0.81	2.00
1930	80.00	100.00	2.70	0.8	10.00
1945	78.00	100.00	1.30	0.7	7.00
2000	72.00	90.00	1.00	0.7	2.50
2015	68.00	87.00	0.7	0.68	6.00

Table 10.1 (Concluded)

TIME (PST)	50' FROM END OF INSTRUMENT DRIFT	INTERSECTION OF INSTRUMENT DRIFT AND MAIN DRIFT	10' OUTSIDE BLAST DOOR MAIN DRIFT	50' OUTSIDE BLAST DOOR MAIN DRIFT	TOP OF SAND PLUG MAIN DRIFT
2030	65.00	85.00	0.6	0.65	10.00
2045	60.00	80.00	0.55	0.6	7.00
2100	55.00	72.00	0.5	0.6	10.00
2115	52.00	70.00	0.45	0.55	10.00
2130	50.00	70.00	0.42	0.5	8.00
2145	50.00	65.00	0.4	0.5	10.00
2200	48.00	62.00	0.4	0.49	12.00
2215	45.00	60.00	0.38	0.45	15.00
2230	42.00	57.00	0.38	0.42	15.00
2245	40.00	52.00	0.31	0.4	15.00
2300	38.00	50.00	0.3	0.4	15.00
2315	33.00	50.00	0.3	0.38	12.00
2330	32.00	48.00	0.28	0.35	12.00
2345	30.00	45.00	0.26	0.3	11.00
2400	30.00	42.00	0.255	0.3	11.00

Upon direction from Radsafe Control:

1. Survey Team No. 1 proceeded along the Area 15 access road to the U15a shaft area reporting all measurements enroute. The team obtained readings at the shaft entrance and other locations of interest in the surrounding area. Team No. 1 then established a radex area around the shaft area with signs and barricades. At the direction of Radsafe Control, Team No. 1 returned to the FCP to act as party monitors for the surface recovery teams.

2. Radsafe Survey Team No. 2 proceeded along the Area 15 main access road to the Sandia Trailer Park, surveying enroute. From this point Team No. 2 converged on the U15e shaft area along with Team No. 1. After completing the survey of the shaft entrance, Team No. 2 went to SGZ (approximately 200 feet northeast of the shaft entrance) and surveyed the area for cracks and fissures. After completing these surveys, Team No. 2 returned to the FCP and waited for further assignments.

Sufficient Radsafe personnel were standing by at the FCP to provide rescue and emergency support, if needed, and to implement radiological area control as exclusion areas were established. A mobile facility for issue of anticontamination equipment, portable instruments, and dosimetric devices was positioned at the FCP. A mobile decontamination unit was positioned adjacent to it.

Each area and all contaminated or radioactive materials were marked to indicate radiation levels. Personnel entering radiation areas or working with contaminated material were briefed concerning potential exposure and safety precautions and were provided with anticontamination clothing, equipment, and materials.

Decontamination units later were repositioned at entrances

TABLE 10.2

TINY TOT EVENT

INITIAL RADIATION SURVEY DATA
17 June 1965

Time	Location (from SGZ)	Gamma Exposure Rate (mR/h)
1038	Radsafe road stake 10C1 (3 miles SE)	Bkg*
1040	Radsafe road stake 15C5 (1-3/4 miles SE)	Bkg
1044	Sandia Corporation trailer compound	Bkg
1045	Radsafe road stake 15C13 (1/4 mile N)	Bkg
1045	Stanford Research Institute trailer compound	Bkg
1050	200 feet northwest of U15e	0.3
1100	Instrument holes A, B, and C	Bkg
1105	100 feet south of green brock house	55.0
1134	200 feet northwest of U15e shaft	0.2
1145	200 feet northwest of U15e shaft	0.3
1200	U15e shaft collar	300.0

*Natural radiation Background

to controlled radiation areas. Personnel and equipment were monitored and decontaminated as necessary. Drill rigs and associated equipment used in postevent activities also were monitored and decontaminated as necessary.

10.3.3 Experiment Recovery

Two personnel each from EG&G, BRL, DASA, and DOW, and one person from SC reentered the area to perform experiment recoveries on D-day.

10.4 POSTEVENT ACTIVITIES

10.4.1 Postevent Drilling

Postevent drilling began on 27 August 1965 at 2240 hours and was completed on 18 September 1965 at approximately 2125 hours. No radiation levels above background were detected on the drill platform during drilling operations. No radiological problems were encountered.

10.4.2 Shaft Reentry

Shaft reentry operations began at 1030 hours on 2 September 1965. Several tasks were accomplished during work to clear the shaft. These included general shaft repair, installing power lines, lowering vent lines, installing a water pump, and pumping out the shaft. The shaft was cleared on 22 September. No radiological problems occurred during this operation; radiation readings were consistently background.

10.4.3 Tunnel Reentry

Mining began in the tunnel on 24 September 1965. The immediate objectives were to reach the blast door and to drill a 3-

inch hole and run a probe to the instrument drift. Labor strife which began on 28 September caused the DOD official in charge of TINY TOT to close down the effort until after labor problems were settled. Work resumed on 5 November. A new drift was mined from the main drift to the hook drift, and this instrument drift was reached on 10 November.

Breakthrough to the cavity was achieved on 18 November. Radsafe personnel checked water from the cavity and found a trace of alpha contamination. Miners who had been working in this area were told to leave wet anticontamination clothing, gloves, and booties at the hook drift entrance, and these personnel were taken to the CP-2 decontamination facility to shower. At the request of DOD, a television camera was put into the cavity on 22 November to check the water level.

Instrument recovery from the hook drift was performed by one DOD and two SRI personnel on 24 November. All men had contamination on their hands reading up to 0.2 mrad/h. This was removed with one washing. Work in the cavity area continued from 18 November 1965 through 14 January 1966. All personnel were completely "dressed out" in anticontamination clothing and equipment, including two sets of coveralls. A hot line was maintained downhole near the reentry drift.

The cavity was entered on 2 December 1965 by a DOD photo party. Radiation readings were 700 mR/h gamma and greater than 100,000 c/m/55cm^2 alpha. From 2 December until 9 December gravel was poured into the cavity. When miners and one Radsafe monitor entered the cavity on 9 December to level the gravel, the radiation reading was 1 R/h.

Because miners would have to stay for some time in this area while hand shoveling, they were removed from the cavity until information could be obtained concerning authorization to work at this radiation exposure level. The Radsafe supervisor recommended that each miner entering the work area wear at least two dosimeters so that exposure levels could be monitored easily. Exposures estimated with pocket dosimeters were not to exceed 600 mR, and the above requirements were contingent upon approval from the mining supervisor. All downhole work was suspended at 1915 hours on 9 December.

At 2245 hours, two Radsafe monitors entered the cavity and obtained readings shown in Table 10.3. Upon exit, dosimeters of the monitors read 150 mR and their film badges were changed. They were in the cavity approximately 10 minutes.

On 10 December, the allowable personnel exposure was increased to 1 R. Work in the cavity continued. By 14 December the general work area read 2.5 R/h and Radsafe was instructed to keep personnel who already had high exposures out of the area until their dosimeter readings could be checked against their film badges.

DOD photo parties were in the cavity periodically from 3 January 1965 to 12 January 1966 when recovery operations were completed.

10.4.4 Industrial Safety

Checks were made on each shift for radiation levels, toxic gases, and explosive mixtures. These measurements were recorded in the monitor's log book. Industrial safety codes, including specific codes for mining, tunneling, and drilling, were established by REECo and emphasized during all operations.

10.5 RESULTS AND CONCLUSIONS

Telemetry coverage began at zero time on 17 June and con-

TABLE 10.3

TINY TOT EVENT

CAVITY RADIATION READINGS
9 December 1965

Location	Beta Plus Gamma (rad/h)	Gamma (R/h)	Distance from Wall
North	2.0	1.5	3 feet
East	3.2	2.0	1 foot
South	1.5	1.0	2 feet
West	3.0	2.5	1 foot
Center	0.7	0.6	
Entrance	0.5	0.4	Contact

tinued until 0800 hours on 18 June 1965. The maximum reading underground was greater than 1,000 R/h at the intersection of the instrument drift and the main drift (Station 2) at five minutes after detonation. The maximum reading on the surface was 0.750 R/h at the shaft collar 15 minutes after detonation.

The initial reentry survey began at 1038 hours and was completed at 1200 hours on 17 June 1965. The maximum gamma radiation reading was 300 mR/h at the U15e shaft collar at 1200 hours.

No radiation levels above background were detected on the drill platform during postevent drilling operations which began 29 August and were completed 18 September 1965.

Tunnel reentry began on 24 September 1965 and the cavity was entered on 2 December 1965. The maximum radiation reading was 2.5 R/h during cavity reentry on 9 December 1965. Alpha radiation readings were greater than 100,000 $c/m/55cm^2$ during the cavity survey on 9 December 1965.

Personnel exposures received during entries to TINY TOT radex areas from 17 June 1965 through 12 January 1966 are summarized below. Maximum exposures are from film dosimeter records. Average exposures are from self-reading pocket dosimeters as recorded on Area Access Registers.

	No. of Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All Participants	1,575	1,060	24
DOD Participants	96	120	32

Toxic gas levels were 9,000 ppm CO_2 in the instrument drift on 11 October 1965. No explosive mixtures were detected.

No radioactivity above normal background levels was detected offsite by ground and aerial monitoring teams, by stationary exposure rate recorders, or in any environmental samples either after the detonation or during the subsequent sample recovery operations. No prefilter air samples contained levels of gross beta activity above normal background.

REFERENCE LIST

References are not indicated within the text of this report, but are included in this list by chapter or part. Most references are available for review at, or through, the DOE/NV Coordination and Information Center (CIC). Security-classified references are located at the DNA/HQ Technical Library in Alexandria, Virginia, but are available only to persons with appropriate security clearances and a need for classified information contained in the references.

The CIC is operated by REECo, the custodian of nuclear testing dosimetry and other radiological safety records for DOE/NV, and the custodian for DNA of reference documents for reports on DOD participation in atmospheric, oceanic, and underground nuclear weapons testing events and series. Arrangements may be made to review available references for this report at the CIC by contacting one of the following:

Health Physics Division
Department of Energy
Nevada Operations Office
2753 South Highland Avenue
Post Office Box 14100
Las Vegas, NV 89114

Commercial: (702) 734-3194
FTS: 598-3194

or

Archivist, Coordination and Information Center
Reynolds Electrical & Engineering Co., Inc.
Post Office Box 14400
Las Vegas, NV 89114

Commercial: (702) 734-3671
FTS: 598-3671

Source documents available through the National Technical Information Service (NTIS) may be purchased from NTIS at the address and telephone number listed below:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Commercial: (703) 487-4650
(Sales Office)

References available through public bookstores, through the U.S. Government Printing Office, and only at the CIC are listed without asterisks. Asterisks after references or groups of references indicate availability as follows:

* Available through the NTIS and also located at the CIC.

** Located in the REECo Technical Information Office adjacent to the CIC, available through the CIC, and may be subject to Privacy Act restrictions.

*** Located in the DNA/HQ Technical Library, and subject to security clearance requirements.

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13. Atomic Energy Commission, Nevada Operations Office, *Report of the Test Manager, Operation Whetstone*, 1 July 1964 through 30 June 1965, NVO-25, April 1966, Unpublished.

14. REECo Environmental Sciences Department field record archives are maintained chronologically and by test event and include the following:

    a. Procedures, Reentry Plans, Radsafe Plans, and Schedules of Events. **
    b. Correspondence. **
    c. Reports, including onsite Radsafe and offsite PHS event reports. **
    d. Exposure reports, Radsafe log books, Area Access Registers, radiation survey forms, telemetry forms, and other sampling and dosimetry forms. **

APPENDIX A

GLOSSARY OF TERMS

Access Shaft Headframe	A framed structure above the shaft collar, necessary for lowering and hoisting the elevator cage, personnel, and equipment in tunnel shafts.
Activation Products	Nuclides made radioactive by neutrons from a nuclear detonation interacting with usually nonradioactive nuclides. Also called induced activity.
Advisory Panel	A group of experts formed to advise the user (see Testing Organizations) Test Director concerning operational factors affecting a test detonation.
Air Support	Aircraft, facilities, and personnel required for various support functions during testing, such as cloud sampling, cloud tracking, radiation monitoring, photography, and personnel and equipment transport.
Alpha Particle	A particle emitted spontaneously from a nucleus of a radionuclide, primarily heavy radionuclides. The particle is identical with the nucleus of a helium atom, having an atomic mass of four units and an electric charge of two positive units.

Anticontamination Clothing — Outer clothing worn to prevent contamination of personal clothing and the body, and spread of contamination to uncontrolled areas.

Atmospheric Test Series — Each of several series of U.S. tests conducted from 1945 to 1962, when nuclear device detonations and experiments were conducted primarily in the atmosphere.

Attenuation — The process by which photons or particles from radioactive material are reduced in number or energy on passing through some medium.

Background Radiation —

1) Natural environmental radiation.

2) The radiations of man's natural environment, consisting of cosmic rays and those which come from the naturally radioactive atoms of the Earth, including those within man's body.

3) The term also may mean radiation extraneous to an experiment.

Ball Valve — A solid sphere with an opening through it on a diameter which may be aligned with the valved conduit in open position or turned perpendicular to the conduit in closed position.

"Beer Mug" Dosimeters	Dosimetric devices installed in a protective shield the size and shape of a beer mug (see Dosimeter).
Beta Particle	A negatively charged particle of very small mass emitted from the nucleus of a radionuclide, particularly from the fission product radionuclides from nuclear detonations. Except for origin, the beta particle is identical with a highspeed electron.
BJY	The intersection of Mercury Highway with roads originally constructed for the BUSTER-JANGLE 1953 atmospheric test series, located at the NW corner of Area 3 on the NTS.
Blast Door	May be in blast plug, but originally was in its own keyed plug toward the portal from the blast plug. Evolved into an overburden plug with a large steel door containing a smaller access hatch and designed to withstand up to 1000 psi overpressure. May be welded or bolted closed during detonation. Sometimes a loosely used substitute term for a gas seal door.
Blast Plug	Barrier constructed underground as a primary containment feature. May be constructed with sandbags (see Sandbag Plugs), solid sand backfill, concrete (see Keyed Concrete Plug), or other materials. Some plugs may have open-

	ings through them that are sealed with blast doors, and sometimes sandbags are added to protect the opening temporarily during detonation.
Bluebird Teams	Vehicle-borne teams consisting of 2 radiation monitors, each with equipment and materials, to distinguish, follow, delineate, and sample at ground level any effluent release from a nuclear detonation at the NTS. They usually were positioned within the secured area to be free to move about as directed without having to gain access through security stations into the test area.
Button up Activities	Preparations made prior to a detonation during which time all facilities and areas were secured as required, vehicles and equipment were removed, and fixtures were prepared to withstand detonation shock.
Cable Drift	A passageway tunnel, usually parallel to the LOS drift, also known as the access or reentry drift, in which cables from various experiments in the LOS pipe were installed toward a cable alcove and then through a sealed shaft to the surface.
Cal Seal	A commercial sealant that is high density, quick-drying, high-strength, and resilient concrete.

Chamber	A natural or man-made enclosed space or cavity.
Check Points or Check Stations	Geographic locations established and staffed to control entry into restricted areas.
Chimney	The volume of broken rock above an underground detonation cavity that falls downward when decreasing cavity gas pressure can no longer support the column of broken rock.
Cloud Sampling	The process of collecting particulate and gaseous samples of an effluent cloud to determine the amount of airborne radioactivity, and/or for subsequent analysis of detonation characteristics. Sampling usually was accomplished by specially equipped aircraft.
Cloud Tracking	The process of monitoring and determining the drift and movement of an effluent cloud, either by radar or by radiation monitoring and visual sighting from aircraft.
Coaxial Cable	A high-frequency telephone, telegraph, television, or scientific data transmission cable consisting of a conducting outer metal tube enclosing and insulated from a central conducting core.
Collar	See "Shaft collar".

Console	A cabinet or panel containing instrumentation for monitoring or controlling electronic or mechanical devices.
Containment	The process of confining radioactive products of a nuclear device detonation underground.
Contamination	1) Radioactive material in an undesirable location, usually fission and activation products of a nuclear detonation, or fissionable material from a device, incorporated with particles of dust or device debris. 2) The process of depositing radioactive material on, or spreading it to, an undesirable location, such as on personnel, structures, equipment, and other surfaces outside a controlled area.
Crater	The depression formed on the earth's surface by a near-surface, surface, or underground detonation. Crater formation can occur by the scouring effect of airblast, by throw-out of broken surface material, or by surface subsidence resulting from underground cavity formation and subsequent rock fall, or chimneying to the surface.
Crater Experiment	A test designed to breach and excavate the ground surface, thereby forming an

	ejecta crater; as opposed to a sink or subsidence crater.
D-Day	The term used to designate the day on which a test takes place.
D + 1 day	The first day after a test event.
Decontamination	The reduction of amount or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination; (2) letting the material stand so that the radioactivity is decreased as a result of natural decay; or (3) fixing and covering the contamination to attenuate the radiation emitted.
Device	Nuclear fission or fission and fusion materials together with the arming, fusing, firing, chemical explosive, canister, and diagnostic measurement equipment, that have not reached the development status of an operational weapon.
DOD	The U.S. Department of Defense. The federal executive agency responsible for the defense of the United States. Includes the military services and special joint defense agencies.

Dose	A quantity (measured or accumulated) of ionizing (or nuclear) radiation energy absorbed by a medium, including a person.
Dose Rate	As a general rule, the amount of ionizing (or nuclear) radiation energy that an individual or material would absorb per unit of time. Dose rate is usually expressed as rads (or rems) per hour or multiples or divisions of these units.
Dosimeter	An instrument or device used to indicate the total accumulated dose of (or exposure to) ionizing radiation. Instruments or devices worn or carried by individuals are called personnel dosimeters.
dpm	Disintegrations per minute; a measure of radioactivity. Literally, atoms disintegrating per minute.
Draeger Multi-Gas Detector	An instrument used to detect toxic gases, such that a sample of the ambient atmosphere is drawn through a selected chemical reagent tube which indicates the concentration of a toxic gas.
Dressed-Out	Dressed in anticontamination clothing and associated equipment.

Drift	A secondary passageway tunnel, usually horizontal, from or between main tunnels or shafts.
Drillhole Designations	PS-1V: Post-Shot drill hole number 1 - vertical PS-1D: Post-Shot drill hole number 1 - directional PS-1A: Post-Shot drill hole number 1 - angle Each 'S' added after any of the above notations indicates a "sidetrack" or change of direction in the drillhole.
Dry Runs	Rehearsals or practices in preparation for an actual test event.
Effects Experiments	Experiments with the purpose of studying the effects of a nuclear detonation environment on materials, structures, equipment, and systems. Includes measurements of the changes in the environment caused by the nuclear detonation, such as ground movement, air pressures (blast), thermal radiation, nuclear radiation, and cratering.
Explosimeter	A battery-operated detector calibrated to indicate the concentration in the ambient atmosphere of explosive gases and vapors as percent of the lower ex-

	plosive limit (LEL) of hydrogen or methane gas.
Explosive-Proof Flashlight	A flashlight constructed in such a manner that its use will not cause or create an explosion in an explosive gas atmosphere.
Exposure	A measure expressed in roentgens (R) of the ionization produced by gamma rays (or x-rays) in air [or divisions of R, 1/1000 R = milliroentgen (mR)]. The exposure rate is the exposure per unit of time, usually per hour but sometime smaller or larger units (e.g., R/min, R/day, mR/h).
Fast Gate	A closure system driven by explosives or compressed air that closes an opening or conduit within a small fraction of a second.
Film Badge	Used for the indirect measurement of exposure to ionizing radiation. Generally contains 2 or 3 films of differing sensitivity. Films are wrapped in paper (or other thin material) that blocks light but is readily penetrated by radiations or secondary charged particles resulting from radiations to be measured. The films are developed and the degree of darkening (or density) measured indicates the radiation exposure. Film dosimeters commonly are used

	to indicate gamma and x-ray exposures, and also can be designed to determine beta and neutron doses.
Fission	The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with an accompanying release of energy. The most important fissionable, or fissile, materials are uranium-235 and plutonium-239. Fission is caused by the absorption of a neutron.
Fission Products	A general term used for the complex mixture of radioactive nuclides (see Radionuclides) produced as a result of nuclear fission.
Fissionable Material	A synonym for fissile material, also extended to include material that can be fissioned by fast neutrons only, such as uranium-238. Used in reactor operations to mean reactor fuel.
Forward Control Point	A geographic location in the forward test area, usually adjacent to the closed (or secured) test area.
Fusion	The combination of two very light nuclei (of atoms) to form a relatively heavier nucleus, with an accompanying release of energy. Also called thermonuclear fusion.

Gamma Rays	Electromagnetic radiations of high energy emitted from the nuclei of radionuclides, or bundles of energy called photons, which usually accompany other nuclear reactions, such as fission, neutron capture, and beta particle emission. Gamma rays, or photons, are identical with x- rays of the same energy, except that x-rays result from electron reactions and are not produced in the nucleus.
Gamma Shine	Measurable gamma radiation intensity from an approaching radioactive cloud or passing cloud, as opposed to measurements from or in gamma emitting fallout. Also gamma radiation scattered by air molecules, as opposed to direct radiation from a gamma source.
Gas Seal Door	A door constructed in a tunnel gas seal plug. Both are designed to prevent venting of gases, are secondary containment features, and usually are the closest barrier to the portal.
Gas Seal Plug	A plug, employing epoxy, plastic, concrete or other material, designed and installed to prevent the passage and venting of gases (see Keyed Concrete Plug).
Geiger-Mueller Counter	An instrument consisting of a Geiger tube and associated electronic equip-

	ment used to detect and measure (and sometimes record) nuclear radiation.
Geophones	Electronic instruments which detect and record rock falls and earth movements by the use of sound.
Ground Zero	The point on the ground or water at which a surface, near surface, tower-type, or ballon-type nuclear detonation occurs; as opposed to an airburst where the detonation is high in the air, or an underground detonation where the surface is relatively unaffected (see Surface Ground Zero).
H-Hour	Time zero or exact time of detonation to the minute, second, or fraction of a second; as opposed to H + 1 which implies one hour after detonation, unless time units of seconds or minutes are listed.
Hard Copy	The original paper document used in research.
Hot Line	A location on the edge of a radex area where exiting personnel remove anticontamination clothing and equipment and are monitored for contamination and decontaminated as necessary before release.
Ion	An atomic particle or part of a molecule bearing an electric charge, usual-

ly a positively charged ion and a negatively charged ion are formed as a pair (e.g. A negatively charged electron displaced from its positively charged remaining atom).

Ionizing Radiation	Any particulate or electromagnetic radiation capable of producing ions, directly or indirectly, in its passage through air or matter. Alpha and beta particles produce all ion pairs directly, while the electrons of initial ion pairs produced by gamma rays and x-rays in turn produce secondary ionization in their paths.
Isotopes	Different types of atoms within the same element, all reacting approximately the same chemically, but differing in atomic weight and nuclear stability. For example, the element hydrogen has three isotopes; normal hydrogen is the most abundant, heavy hydrogen is called deuterium, and radioactive hydrogen is the radioisotope called tritium.
Keyed Concrete Plug	A concrete plug of greater diameter than the shaft or tunnel cross section, such that the concrete is poured into the surrounding rock, providing greater strength against overpressure from the nuclear detonation.
Leukemia Cluster	An apparent but unexpected or extraordinary group of leukemia cases within

	some number or group of persons.
LOS Tunnel (as opposed to LOS Pipe)	A mined opening for installation of the LOS pipe.
LOS Pipe	A line-of-sight pipe pointed at a device. A large diameter pipe, hundreds of feet long, constructed underground, and from which air has been evacuated to simulate high altitude conditions.
Manhattan Engineer District	The U.S. Army predecessor organization to the U.S. Atomic Energy Commission.
Manned Stations	Locations inside the closed and secured area which are occupied by authorized personnel during an event.
Microbarograph	An instrument that measures and records small changes in atmospheric pressures.
mR	A radiation exposure term (see Exposure).
Noble Gases	Those inert gases which do not react with other elements at normal temperature and pressure, (i.e., helium, neon, argon, krypton, xenon, and radon).
Nuclear Device (vs. weapon or bomb)	A device in which most of the energy released in a detonation results from reactions of atomic nuclei, either fis-

sion, or fission and fusion. A device under development (see Device) is not considered a weapon or bomb. Both A- (or atomic) bombs and H- (or hydrogen) bombs could be called atomic weapons because both involve reactions of atomic nuclei. However, it has become customary to call weapons A-bombs if the energy comes from fission, and H-bombs if most of the energy comes from fusion (of the isotopes of hydrogen - see definition). A developmental nuclear device is not a weapon or weapon component until it can be mated to a delivery system.

Nuclear Device Tests — Tests carried out to supply information required for the design, improvement, or safety aspects of nuclear weapons, and to study the phenomena and effects associated with nuclear explosions.

Nuclear Weapon Tests — Tests to provide development and weapons effects information, which may or may not utilize a deliverable nuclear weapon.

Overburden Plug — A keyed concrete plug toward the portal from the blast plug, containing a blast door, and withstanding pressures as high as the rock above GZ to the surface, or overburden, could withstand.

Party Monitors	Radiation monitors assigned to reentry and recovery parties or groups.
Privacy Act	The Privacy Act of 1974. Public Law 93-579. An Act to amend Title 5, U.S. Code, by adding Section 552a to safeguard individual privacy from the misuse of federal records, to provide that individuals be granted access to records concerning them which are maintained by Federal agencies, to establish a Privacy Protection Study Commission, and for other purposes.
rad	Abbreviation for radiation absorbed dose. A unit of absorbed dose of radiation representing the absorption of 100 ergs of ionizing radiation per gram of absorbing material, including body tissue.
Radex Area	An acronym for radiation exclusion area. A radex area is any area which is controlled for the purpose of protecting individuals from exposure to radiation and/or radioactive material.
Radiation Exposure	Exposure to radiation may be described and modified by a number of terms. The type of radiation is important: external exposure is to beta particles, neutrons, gamma rays and X-rays; or exposure may be internal from radionuclides deposited within the body emitting alpha, beta, gamma or x-radiation and

	irradiating various body organs. (see Dose and Exposure).
Radioactive Effluent	The radioactive material, steam, smoke, dust, and other particulate debris released to the atmosphere from an underground nuclear detonation.
Radioactive or Fission Products	A general term for the complex mixture of radionuclides produced as a result of nuclear fission (see Activation Products).
Radionuclides	A collective term for all types of radioactive atoms of elements; as opposed to stable nuclides (see Isotopes).
Recovery Operations	Process of finding and removing experiments, by-products, or results from the test area after a test event.
rem	A special unit of biological radiation dose equivalent; the name is derived from the initial letters of the term "roentgen equivalent man or mammal." The number of rem of radiation dose is equal to the number of rad multiplied by the quality factor (QF) and the distribution factor (DF) of the given radiation.
roentgen	A special unit of exposure to gamma (or X-) radiation. It is defined precisely as the quantity of gamma (or X-) rays

	that, when completely stopped, in air, will produce positive and negative ions with a total charge of 2.58×10^{-4} coulomb in one kilogram of dry air under standard conditions.
Safety Experiments	Device tests conducted to determine the safety of nuclear weapons during transportation and storage. Elements of the conventional high explosive portions of the devices were detonated to simulate accidental damage and to determine the potential for such simulated damage to result in significant nuclear yield. Data gained from the tests were used to develop devices that could withstand shock, blast, fire, and other accident conditions without producing a nuclear detonation.
Sandbag Plugs	Barriers used in tunnels, constructed of sandbags, to help contain underground detonations and minimize damage to underground workings.
Seismic Motion	Earth movement caused by an underground nuclear detonation, similar to a minor earthquake.
Shaft	A long narrow passage sunk into the earth. Shafts for device emplacement, ventilation, or access to underground workings may be drilled or mined.

Shaft Collar	The area immediately around the shaft at ground level, usually cemented, which supports the headframe and other equipment.
Shield Walls	Walls or barriers used to protect equipment or instrumentation from heat, blast, and radioactivity.
Slushing Operations	The process of moving broken rock with a scraper or scraper bucket. May be used on the surface or underground, where ore or waste rock is slushed into hoppers or other locations for removal.
Spalling	Rock disintegration by flaking, chipping, peeling, or layers loosening on the outside edges. May be caused immediately by rock stressing in proximity to a detonation point. Also results later, after continued stressing from temperature change expansion and contraction. Spalling also may result or begin when rock containing moisture is raised to a high temperature, and expanding vapor creates fractures.
Stemming	The materials used to back-fill or plug the emplacement shaft, drift, or LOS drift to contain the overpressure and radioactive material from a nuclear detonation.
Suitcase Analyzer	A portable radiation analysis instrument used to analyze samples in the

	field or in other locations than a laboratory.
Surface Ground Zero	The location on the ground surface directly above an underground zero point or directly below an airburst.
Test Event	The immediately preceeding preparations for, including arming and firing, and the testing of a nuclear device, including the detonation and concurrent measurements and effects.
Testing Organizations	Organizations conducting nuclear tests at the NTS (see DOD, LASL, LRL and SL).
Trailer Park	The location of modified trailers and vans which contain measurement and recording equipment attached to cables coming from underground detectors and experiments. Usually located at least 900 feet from SGZ.
Tunnel	An underground horizontal or nearly horizontal passageway.
Tunnel Access	Entry to a tunnel or tunnel complex upon approval of the Test Director during test operations, or upon approval of the Tunnel Superintendent during routine operations.

Tunnel Complex	A composite of passageways branching from and including the main tunnel or access tunnel from a shaft.
Tunnel Walk-Out	A visual, walking inspection of the tunnel or tunnel complex, usually as a part of the initial reentry after a detonation, to check for hazards of any and all kinds prior to allowing general access to the underground workings.
Two-Hour McCaa Breathing Apparatus	A self-contained respiratory device that supplies two hours of breathing oxygen.
Underground Structures Program	The construction and fabrication of test structures underground for the purpose of detonation effects evaluation.
User	An organization conducting tests at the NTS (See Testing Organizations).
Vela-Uniform	Department of Defense (DOD) program designed to improve the capability to detect, identify, and locate underground nuclear explosions.
Venting	Release of radioactive material, steam, smoke, dust and other particulate debris through a zone of weakness from the detonation-formed cavity into the atmosphere.

Water Glass	A collodial suspension in water of a sodium silicate compound. A hardening gel commonly used as a preservative, an adhesive, in plaster, and in cement. Used at NTS as a grout to seal cracks and fissures, and, in dilute form, has been sprayed on surfaces for dust and contamination control purposes.
Weapons Effects Experiments	Experiments with the purpose of studying the effects of a nuclear detonation environment on materials, structures, equipment, and systems. Includes measurements of the changes in the environment caused by the nuclear detonation, such as ground movement, air pressures (blast), thermal radiation, nuclear radiation, and cratering.
Weapons Development	See Nuclear Device Tests
Weather Briefings	Meetings of test-associated administrators, advisors, and other technical personnel, prior to each test event, to evaluate weather conditions and forecasts on event day, assure that direction and wind speeds will not cause any resulting radioactive effluent to contaminate populated areas, and make decisions on any necessary operational schedule changes.
Workings	An excavation or group of excavations made in mining, quarrying, or tunnel-

ing, used chiefly in the plural, such as "the workings extended for miles underground."

X-rays — Electromagnetic radiations produced by electron reactions, as opposed to emission of gamma rays by nuclei. Otherwise high energy x-rays are identical with gamma rays of the same energy.

Yield — The total effective energy released by a nuclear detonation. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested as nuclear radiation (including residual radiation), thermal radiation, and blast and shock energy, the actual distribution depending on the medium in which the explosion occurs and also upon the type of weapon.

APPENDIX B

ABBREVIATIONS AND ACRONYMS

The acronyms in the following list are used in Volume I of the DOD underground testing reports. Additional information and definitions may be found in the text and in the Glossary of Terms.

AAS	American Aerial Survey
AEC	Atomic Energy Commission
AFSWC	Air Force Special Weapons Center
AFSWP	Air Force Special Weapons Project
AFWL	Air Force Weapons Laboratory
APC	Army Pictorial Center
ARF	Armour Research Foundation
ARMS	Area Remote Monitoring Station
AVCO/RAD	AVCO Corporation
BAC	Boeing Aircraft Corporation
Bkg	Background Radiation Measurement
BRL	Ballistics Research Laboratory
BTL	Bell Telephone Laboratories
CDC	Center for Disease Control
CETO	Civil Effects Test Organization
CIC	Coordination and Information Center
CO	Carbon monoxide
CO_2	Carbon dioxide
CP-1	Control Point Building 1
CP-2	Control Point Building 2
cps	Counts per second
CTO	Continental Test Organization
DASA	Defense Atomic Support Agency
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
EG&G	EG&G, Inc. (formerly Edgerton, Germeshausen, and Grier)
ERDA	Energy Research and Development Administration
FCDASA	Field Command, Defense Atomic Support Agency
FCDNA	Field Command, Defense Nuclear Agency
FCP	Forward Control Point
FCWT	Field Command, Weapons Test Division
F&S	Fenix & Scisson, Inc.
FSI	Federal Services, Incorporated
GA	General Atomic Corporation
GE	General Electric Corporation
GZ	Ground zero

HDL	Harry Diamond Laboratories
HE	High explosives (conventional)
H&N	Holmes & Narver, Incorporated
HUGHES	Hughes Aircraft Company
ICC	Interstate Commerce Commission
IITRI	Illinois Institute of Technology, Research Institute
ISAFB	Indian Springs Air Force Base
ISO	Isotopes Incorporated
JCS	Joint Chiefs of Staff
kt	Kilotons
LANL	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory (now Los Alamos National Laboratory)
LEL	Lower explosive limit
LLNL	Lawrence Livermore National Laboratory
LMAFS	Lookout Mountain Air Force Station
LMSC	Lockheed Missile and Space Corporation
LOS	Line-of-sight
LRL	Lawrence Radiation Laboratory (now Lawrence Livermore National Laboratory)
MPC	Maximum permissible concentration
MRC	Moleculon Research Corporation
mrem/qt	Millirem per quarter
mrem/yr	Millirem per year
mR/h	Milliroentgens per hour
MSA	Mine Safety Appliance
MSL	Mean sea level
NATS	Nevada Aerial Tracking System
NC	Northrup Corporation
NDL	Army Chemical Corps Nuclear Defense Laboratory
NOB	Nevada Operations Branch
NOL/WO	Naval Ordnance Lab, White Oak
NO_2	Nitrogen dioxide
$NO+NO_2$	Nitric oxide plus nitrogen dioxide
NPG	Nevada Proving Ground
NRDS	Nuclear Rocket Development Station
NTS	Nevada Test Site
NTSO	Nevada Test Site Organization
NVOO	Nevada Operations Office
PDT	Pacific Daylight Time
PHS	United States Public Health Service
ppm	Parts per million
psi	Pounds per square inch
PST	Pacific Standard Time
rad/h	Radiation absorbed dose per hour
Radsafe	Radiological Safety Division, REECo
radsafe	Radiological Safety, in general
RAGS	Remote area gas sampler
RAMS	Remote area monitoring station
RARS	Remote area recording station
RCG	Radioactivity concentration guide
RDS	Remote data station

REECo	Reynolds Electrical & Engineering Company, Incorporated
rem	Roentgen equivalent man or mammal (see Glossary of Terms)
R/h	Roentgens per hour
RMS	Radector monitoring station
RPG	Radiation protection guide
SC	Sandia Corporation (now Sandia National Laboratories)
SGZ	Surface Ground Zero
SL	Sandia Laboratories (now Sandia National Laboratories)
SNL	Sandia National Laboratories
SOP	Standard operating procedures
SRI	Stanford Research Institute
STWT/DASA	Weapons Test Division, Defense Atomic Support Agency
SWC	Special Weapons Center
TC	Test Controller
TCM	Tunnel condition monitor
TGD	Test Group Director
TNT	High explosive chemical (trinitrotoluene)
USAEL	United States Army Electronic Laboratory
USAF	United States Air Force
USC&GS	United States Coast and Geodetic Survey
USGS	United States Geological Survey
USWB	United States Weather Bureau
VA	Veterans Administration
WES	Waterways Experiment Station
WP	Working Point
WSI	Wackenhut Services, Incorporated

APPENDIX C

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GENERAL TUNNEL REENTRY PROCEDURES FOR DEPARTMENT OF DEFENSE AND SANDIA LABORATORY NUCLEAR TESTS

George R. Wenz
Harold L. Rarrick
Health Physics Division, 3312
Sandia Laboratory, Albuquerque

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ABSTRACT

This document describes preshot preparations and postshot procedures for safe and economical reentry into a tunnel area after a nuclear detonation. Associated responsibilities, possible hazards, reentry ground rules, preshot preparations, communications, reentry parties and equipment, initial tunnel reentries, and recovery of scientific experiments are explained.

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Specifically commended are G. A. Clayton, H. D. Edwards, F. J. Solaegui and their initial reentry teams who have performed these duties in very severe environments.

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GENERAL TUNNEL REENTRY PROCEDURES FOR DEPARTMENT OF DEFENSE AND SANDIA LABORATORY NUCLEAR TESTS

1. Introduction

The Health Physics Division began tunnel reentries in 1962. The procedures that are given in this document represent a compilation of a series of tunnel reentry procedures that have been continually improved based upon experience and better instrumentation. The reentry plan presented describes preshot preparations and postshot procedures for safe and economical reentry and scientific recovery in a tunnel area.

2. Responsibilities

Responsibilities for safe and economical tunnel reentry procedures after a nuclear detonation indicated herein for AEC or AEC contractor (i.e., Sandia Laboratory) personnel are in accord with established AEC/DOD agreement or are the subject of separate action between TC/DASA and NVOO.

a. AEC-NVOO

(1) The Test Manager is responsible to the AEC for the safety of all the participating personnel at sites under the jurisdiction of NVOO and has approval authority over decisions effecting the safety of these personnel. (Ref: NTSO Draft 0524-013a.)

(2) The NVOO Operational Safety Division will advise the DOD Test Group Director (TGD) and the Reentry Control Group on all problems pertaining to health and safety.

b. Sandia Laboratory

(1) The Sandia Laboratory Health Physics Division has three responsibilities: It specifies the necessary measuring devices and equipment to indicate the postshot condition of the tunnel; it provides the Reentry Control Group; and it documents any release of radioactive material.

(2) The Chief of the Reentry Control Group will act as advisor to the TGD on surface and tunnel reentry safety until the tunnel has been cleared for normal operation.

(3) The Reentry Control Group will provide consultants who will advise on tunnel reentry procedures. These consultants will be familiar

with the experimental setup and with possible postshot tunnel conditions and hazards.

(4) The Reentry Control Group will arrange the necessary support for reentry and recovery, e.g., it will provide mine rescue trained personnel, Rad-Safe support (see Annex A), Industrial Hygiene Support, etc.

c. TC/DASA or Sandia Laboratory Test Group Director

(1) The TGD is responsible for the safe conduct of all activities in the tunnel area He will authorize and initiate both a tunnel condition survey and reentry and recovery operations with the concurrence of the Test Manager.

(2) The TGD will be responsible for initiating all action for the preshot installation and postshot removal of equipment and services required for Test Group support activities except those items covered as AEC responsibilities in the AEC/DOD agreement.

3. <u>Possible Hazards</u>

a. Radiation. Radiation in tunnel reentry areas may result from any one of the following:

(1) Leak of radioactive gases or materials through fissures or fractures from ground zero.

(2) Failure of the tunnel stemming.

(3) Activation and/or dispersion of samples in the experimental chamber.

b. Explosive or toxic gases. Various explosive and toxic gases released as direct or secondary products of the detonation may be present in concentrations dangerous to personnel.

c. Explosives. Undetonated HE may remain either intact or scattered in the tunnel.

d. Toxic materials. Beryllium may pose a toxic problem to personnel particularly if it becomes dispersed in the air and/or deposited on recovery samples.

e. Tunnel damage. Damage to the tunnel may result from the device generated shock wave.

(1) Collapse of the tunnel would not normally be expected beyond the stemming; however, partial or total collapse may occur at greater distances from ground zero. Reentry through collapse zones must be preceded by mining through broken ground or by driving a new parallel drift.

(2) Heave of the tunnel floor may cause slabbing or spallation of the rock and failure of utility lines, railroad track, tunnel sets, and lagging. This damage will create safety hazards which must be removed prior to experimental recoveries.

f. High pressure gas. High pressure (2200 psi) gas cylinders normally exist within the tunnel complex.

4. Reentry Ground Rules

a. Initial reentry and each subsequent phase will be initiated upon authorization of the TGD with concurrence of the Test Manager, and control will be retained by the TGD until all recovery operations are completed and tunnel access is returned to AEC control. Only those personnel authorized by the TGD and the Chief of the Reentry Control Group will be permitted in the portal area and tunnel.

b. Tunnel communications will be by a hard wire portable phone system.

c. Tunnel parties will be controlled by the Chief of the Reentry Control Group who is located at the tunnel portal. Tunnel parties may be recalled at his direction. Only one team will be in the tunnel at any single time unless directed otherwise by the Chief of the Reentry Control Group.

d. A tunnel party will return to the portal under any of the following conditions:

(1) Upon decision of the Team Chief.

(2) When any member of Teams 1, 2, 3, and 4* show a McCaa oxygen supply less than 30 atmospheres or a Draeger pressure less than 450 psi.

(3) Upon loss of communications with the Reentry Control Group at the portal.

e. Team 4 (Rescue Team) will be dispatched upon direction of the Chief of the Reentry Control Group, the Team Chief in the tunnel, or if communications should be lost with any team in the tunnel (allowing a reasonable time for the team to exit after loss of communications).

f. All observations during reentry will be communicated through the Chief of Party to the Chief of the Reentry Control Group and recorded for future reference.

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*See Paragraph 7, "Reentry Parties and Equipment," for a description of the personnel, function, and equipment of each team.

g. Personnel radiation exposure limits are those set by NTS SOP Chapter 0524. The radiation dose limit for the operation is 3 Rem per calendar quarter. A person's exposure, however, will be terminated when his pocket dosimeter reaches 2.0 Rem, assuming his exposure history would allow 3 Rem during this operation.

h. Tunnel reentry will not be made before the tunnel ventilation has been turned on and samples of the air monitored at the portal. Evaluation of the sample must indicate that reentry can be made within the limitations of this procedure.

i. Reentry will not be made beyond ventilation, 10R/hr, 1000 ppm CO, or 10 percent of the lower explosive limit of explosive gas mixtures. Teams 1, 2, 3, and 4 may be exempted from these requirements under extenuating circumstances by mutual decision of the Chief of the Reentry Control Group and the Chief of the Party.

j. The Rescue Team will always be stationed near the portal with a train for immediate dispatch.

ımmary of Preshot Preparations for Reentry

a. Stemming should provide fireball containment and should reduce radioactivity and explosive gas in the reentry area. The overburden plug should contain any debris that may pass the stemming. The gas seal door should contain any gases that penetrate the overburden plug.

b. Remote radiation sensing instruments will provide knowledge of tunnel radiation levels, while tunnel condition indicators (geophones, pressure and temperature gages, and explosimeters) remotely monitor the tunnel.

c. Air sampling lines for gas chromatography are normally installed through both the gas seal door and the overburden plug. Each installation is provided with suitable remotely operated valves. Samples may be drawn from the inside of the gas seal door, from both sides of the overburden plug, and from near the stemming. Sampling from these lines will help determine the explosive and toxic gas concentrations in the tunnel prior to reentry.

d. Valves are normally installed in the vent lines and makeup ports in the gas seal door and overburden plug. An axial vane fan is located on the makeup valves to reduce negative pressure. The valves and fan are remotely operated from a manned location and will have position monitors to indicate whether they are fully open or fully closed. The position monitors will also show whether the fan power is on or off.

e. The following items ordinarily have power turned on through and after zero time:

(1) Tunnel utilities and instrumentation. Power to these items will be turned off near zero time.

(2) Geophone transmitter trailer. This supplies power to the geophone and the pressure and temperature amplifiers which must be left on to monitor for cavity collapse and pressure changes.

(3) Ventilation fans. Power will be controlled remotely.

(4) Radiation detectors.

(5) Explosimeters.

(6) Ventilation and gas sampling valves. Power will be controlled remotely.

f. The Sutorbilt fans will be installed so they will pull air through the vent line filter system before it is released to the atmosphere. One Sutorbilt fan will be used for a back-up in case the other fan fails.

g. Ventilation.

(1) The ventilation system is installed so that all areas of the tunnel that are not closed off are swept with fresh air from the portal.

(2) After zero time and when the TGD gives his approval (with the consent of the Test Manager), the tunnel ventilation system will be turned on, exhaust and makeup air will be supplied from the portal through valves in the gas seal door and, if possible, the overburden plug. There will be valves that can be remotely operated in both vent lines at the gas seal door and, if possible, at the overburden plug. Vent line samples will be taken to monitor for radioactive, explosive, and/or toxic effluents.

6. Communications

A communication system with the necessary wire on a portable reel will be used during initial reentry. A back-up reel will be available. All conversation between the reentry party and reentry control will be recorded.

7. Reentry Parties and Equipment

The reentry parties will consist of the personnel and equipment described in the following table:

Party Name	Equipment
a. Teams 1, 2, and 3 - Tunnel Reentry Party (1) Chief of Party (2) Rad-Safe monitor (3) Industrial Hygiene monitor (May be performed by Rad-Science personnel) (4) Tunnel safety (5) Scientific Advisor (as required)	Full Radex clothing Bureau of Mines approved 2-hour self-contained oxygen breathing apparatus Radiation detectors Explosive gas meter Toxic gas detectors Oxygen percent meter Hard wire communications
b. Team 4 - Tunnel Rescue Party (1) Chief of Party (2) Three to six REE Co. Mine Rescue (3) Two monitors for Rad-Safe and Industrial Hygiene	Full Radex clothing Bureau of Mines approved 2-hour self-contained oxygen breathing apparatus Radiation detectors Toxic gas detectors Explosive gas meters Wire litters Hard wire communications
c. Team 5 - Tunnel Scientific Assessment Team (as required) (1) Chief of Party (2) Rad-Safe and Industrial Hygiene monitors (3) Scientific Advisors (4) Mine support	Full Radex clothing Respiratory protection (as required) Radiation detectors Toxic gas detectors Explosive gas meter Hard wire communications
d. Team 6 - Tunnel Work Party (1) Chief of Party (2) Rad-Safe and Industrial Hygiene monitors (3) REE Co. Miners	Full Radex clothing Respiratory protection (as required) Radiation detectors Toxic gas detectors
e. Team 7 - Tunnel Scientific Recoveries to Experimental Chamber (see Para. 9 for details)	Full Radex clothing Respiratory protection (as required)
f. Team 8 - HE Disposal Group (as required)	Full Radex clothing Respiratory protection (as required)
g. Team 9 - Medical Support M. D. and medical technician	Necessary medical equipment Ambulance

8. Initial Tunnel Reentries

a. After the event the TGD will review radiation and tunnel condition monitors. When he determines that it is safe, and with the agreement of the Test Manager, the tunnel ventilation system will be turned on EXHAUST. Makeup air will be supplied from the portal through the valves in the plugs.

b. Prior to entry into the tunnel, all experimental cables and all electrical and telephone lines going into the tunnel through the portal will be either locked open or disconnected. All other cables going into the tunnel will be disconnected and taped or cut and grouted as necessary. Along with the pressure, temperature, and geophone instruments, the remote radiation monitoring system and the remote explosimeters will be left connected. No circuit into the tunnel or into the instrumentation trailers will be closed when personnel are either in the tunnel or directly in front of the portal (including an area extending 50 feet on either side of the portal).

The Chief of the Reentry Control Group will advise the TGD on tunnel conditions by reviewing surface conditions, exhaust gas information, tunnel radiation, tunnel condition indicators, and seismic information. This review will determine when tunnel reentry may actually begin.

When cleared by the TGD and the Test Manager and when all surface recoveries and power checks are complete, Team 1 will be allowed to make the initial tunnel reentry. There will be no change in the tunnel ventilation setup or in utilities while Teams 1 through 5 are underground. The number of people in the portal area and trailer parks will be held to a minimum.

c. Team 1 will be the first group to reenter and will proceed to the gas seal door. A train may be used to supply transportation to the gas seal door, conditions permitting. Team 1 will continuously monitor for radioactivity and for toxic and explosive gases. Pressure gages at the gas seal door will be checked, and if no pressure is observed, a sample will be taken through the door to determine the environment on the other side of the door. Under safe conditions, Team 1 will then open the gas seal door. They will inspect the tunnel to the overburden plug. The pressure gages at the overburden plug will be checked and if no pressure is observed, a sample will be taken through the plug to determine the environment on the other side of the plug. Team 1 will then withdraw to the portal area. If remote ventilation has not been established previously behind the overburden plug, the work party (Team 6) will then reenter and take the necessary steps to establish ventilation through the plug. They will then exit the tunnel, and samples will be taken from the vent line to verify earlier remote sampling. A second work party may be required to open the overburden plug door and remove the material from the manway.

Team 2 will reenter with an engine and car containing the necessary equipment to open the overburden plug door. This group will take in the reel of communication wire and connect it up to the existing communication line jack at the overburden plug to reestablish communications with the reentry control group at the portal. Team 2 will open the manway door and will continuously monitor for radioactivity and for toxic and explosive gases. They will then withdraw to the portal with the engine.

Team 3 will reenter to the overburden plug and reestablish communications using the reel connected to the communication line jack. The team will walk out the remaining drift continuously monitoring for radioactivity and for toxic and explosive gases. They will also observe the vent lines to assure themselves that the lines are intact. Team 3 will proceed to the stemming, if possible, noting tunnel and pipe conditions. They will then return to the end of the experimental pipe and establish ventilation in the pipe if time and conditions permit. Swipes will be taken on the vent port of the test chamber and checked for contamination. These will be later analyzed for Be and isotope identification.

The mission of Teams 1, 2, and 3 is to verify that the tunnel complex is within acceptable levels for toxic and radioactive gases and to check the condition of the pipe and tunnel.

d. If Teams 1, 2, and 3 determine that tunnel rehabilitation may be safely conducted, they will leave the tunnel and Team 6 will make temporary repairs as needed to the vent line or tunnel. A Rad-Safe monitor will remain with Team 6 while in the tunnel and continue to monitor for radiation and toxic gases.

e. The object of Teams 1 and 3 will be to explore as much of the tunnel on one reentry as possible. Previous experience has shown that McCaa or Draeger Teams can explore up to 4300 feet in 1-1/2 hours with a 1/2 hour safety margin. If an additional initial reentry is required to fully explore the tunnel, Team 4 (with Rad-Safe and Industrial Hygiene monitors) will complete the tunnel exploration with Team 1 standing by as Tunnel Rescue.

9. Tunnel Scientific Recoveries from the Experimental Chamber

a. Scientific recoveries in the tunnel will not be permitted until Team 1, 2, or 3 has searched all drifts and verified that the tunnel is clear of dangerous amounts of toxic, explosive, and radioactive gases.

b. Before scientific recoveries may begin, repair of the tunnel along the recovery route to the experimental chamber must be complete. This activity may include repairing broken lagging and removing hazardous obstacles as well as repairing railroad track and vent lines. The tunnel lights will be turned on before all scientific recoveries except film recoveries begin. All cabling extending into a crushed zone will be cut.

c. Team 5 will conduct a technical survey and perform the necessary actions to begin scientific recoveries.

d. Team 7 will then be permitted to proceed to the experimental chamber and begin the removal of samples in order of priority. A Rad-Safe/ Industrial Safety monitor will be present at all times. This monitor will advise the Chief of the Reentry Control Group, who is responsible for terminating scientific recovery, whenever the tunnel environment becomes dangerous. A Rad-Safe check station will be established at each Scientific Station to control contamination.

APPENDIX D

U. S. ATOMIC ENERGY COMMISSION
STANDARD OPERATING PROCEDURE
NEVADA TEST SITE ORGANIZATION

NTSO-0524-01

Chapter 0524 RADIOLOGICAL SAFETY

0524-01 Radiological Safety

011 Purpose

The purpose of this Standard Operating Procedure is to define responsibility and to establish criteria and general procedures for radiological safety associated with NTS programs. Additional operational instructions relating to radiological safety for particular activities may be published as a part of the Test Manager's Operational Plan.

012 Responsibilities

a. Test Manager. The Test Manager is responsible to the AEC for the protection of participating personnel and off-site populations from radiation hazards associated with activities conducted at the NTS. By mutual agreement between the Test Manager and a scientific user, control of rad-safety within the area assigned for a particular activity may be delegated to the user's Test Group Director during the period of time when such control could have a direct bearing on the success or failure of the scientific program.

b. Test Group Director. Whenever operational rad-safety control is delegated to a Test Group Director under provisions of 012a above, he is responsible to the Test Manager for establishment and notification of safety criteria within the assigned area. Under such conditions, he will be responsible for submitting a detailed rad-safety operational plan to the Test Manager for concurrence.

c. Area Manager, LVAO. The Area Manager is delegated the on-site rad-safety responsibility for the NTS, except for those periods in which operational control of specified areas may be delegated to the Test Group Director under 012a above.

The Area Manager is also delegated responsibility for the off-site radiological safety operations associated with NTS activities.

d. Radiological Safety Advisor. The NTSO Rad-Safety Advisor is responsible to the Test Manager for staff supervision of rad-safety policies and procedures at the NTS.

e. AEC Radiological Safety Officer. The AEC Radiological Safety Officer is responsible to the Area Manager, LVAO, for the direction and coordination of the on-site and off-site rad-safety programs, except for those periods when operational control of specified areas is delegated to a Test Group Director under 012a above.

f. Off-Site Radiological Safety Officer. The Officer-in-Charge, U. S. Public Health Service Off-Site Activities Office, LVAO, is designated as the Off-Site Rad-Safety Officer and is responsible to the Area Manager, LVAO, through the AEC Rad-Safety Officer, for operation of the off-site program.

g. Project Manager, Reynolds Electrical and Engineering Co., Inc. The Project Manager provides on-site rad-safety support services to the Area Manager, LVAO, and to Test Group Directors as required.

h. Participating Agencies. The official in charge of each agency or organizational group participating in NTS field activities is responsible to the appropriate NTSO official designated above for compliance by his personnel with established rad-safety policies, procedures and controls. Each official in charge of a participating group is also responsible at all times to his parent organization for the radiological safety of personnel under his supervision.

0524-02 Organization

The chart showing the organizational relationship of the rad-safety activities is shown in Figure I on the following page.

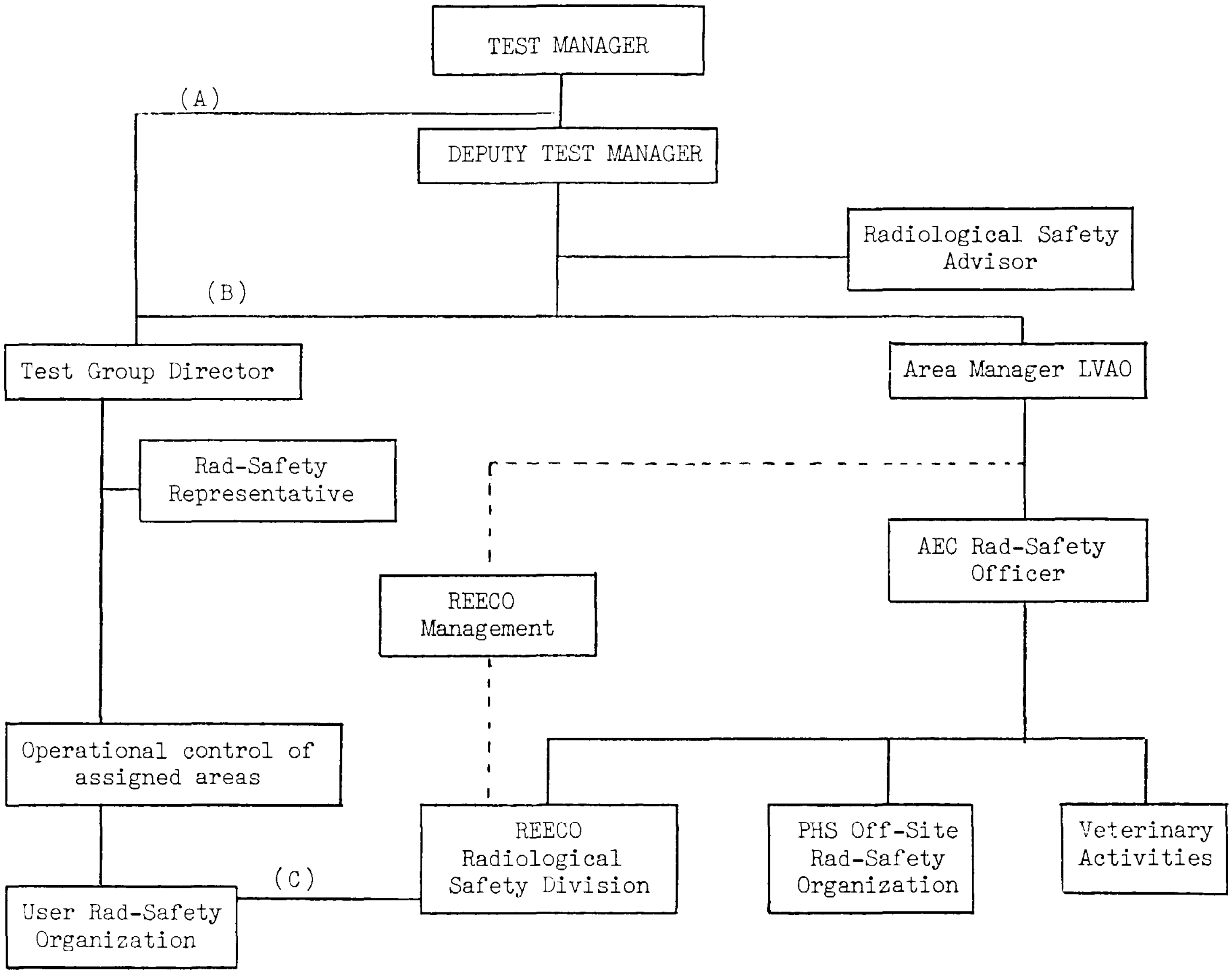
0524-03 Radiation Incidents Reports

See NTSO Chapter 0502 and NTSO Appendices 0502-04, A, B, and C for detailed reporting procedures.

0524-04 On-Site Rad-Safety Operations

041 Purpose

The purpose of this on-site plan is to set forth procedures to be followed by all participants in connection with on-site rad-safety operations at the Nevada Test Site.



------ Administrative
(A) Policy
(B) Normal Operations
(C) When requested by User

FIGURE I ORGANIZATION CHART, RAD-SAFETY ACTIVITIES

042 Definition of On-Site Terms

a. Certified Monitor: Any person certified to the Test Manager or his designated representative as a qualified monitor by a Test Group Director or his Radiological Safety Representative.

b. RPG: Radiation Protection Guide is the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation dose as far below this guide as practicable.

c. RCG: Radioactivity Concentration Guide is the concentration of radioactivity in the environment which is determined to result in whole body or organ dose equal to the Radiation Protection Guide.

d. MPD: The Maximum Permissible Dose in rems that can be accumulated at any age is equal to five times the number of years beyond age 18, thus MPD = 5 (N-18) where N is the age.

e. NTS: The Nevada Test Site, excluding Desert Rock and Area 51, but including Mercury and the Jackass Flat area.

f. On-Site: The area within the NTS boundaries including Mercury.

g. Radex: Radiological Exclusion Area.

h. Controlled Area: Refers to any area within the NTS boundaries where for safety or any other purpose it is necessary to control entry of personnel.

i. User: Those organizations having an approved technical program.

j. REECo: Reynolds Electrical & Engineering Company, Inc., the support contractor for the Nevada Test Site.

043 Responsibilities

a. The Project Manager, REECo, is responsible to the Area Manager, LVAO, for furnishing radiation safety support services as follows:

1. Providing rad-safety support, including qualified monitors, to user organizations as required.

2. Making radiological surveys, mapping and properly marking all contaminated areas, and distribution of this survey information.

3. Conducting a personnel radiation dosimetry program.

4. Maintaining and calibrating radiation detection equipment.

5. Procuring, issuing, and decontaminating rad-safety clothing, supplies, and equipment as required.

6. Providing radioactive source material and waste disposal control within the Nevada Test Site.

7. Operating personnel- and equipment-decontamination facilities.

8. Providing advice and assistance in matters pertaining to radiological safety.

9. Conducting occupational and bio-assay program.

10. Providing necessary support services for the off-site rad-safety program as required.

11. Conducting rad-safety training courses as required.

12. Preparing final on-site reports containing radiological data following each test operational period, special reports as requested, and detailed operational plans for each future program.

13. Providing a stand-by emergency monitoring team to handle unforeseen incidents associated with radiation.

14. Providing a repository for records and source documents pertaining to personnel dosimetry for all OTO field activities and all prior weapons test series.

15. Conducting analysis of samples for radioactivity and for certain toxic materials.

b. The Support Contractor will prepare and keep current a manual containing the Standard Operating Procedures (SOP) for providing rad-safety support services to users and contractors at NTS as outlined in 043a above.

c. Whenever a Test Group Director has been delegated responsibility for on-site rad-safety under subsection 012a above, the Test Manager's operation order will specifically list those functions in subsection 043a for which the Support Contractor will be responsible to the Test Group Director.

044 Radiation Protection Guides

a. Radiation Exposure Criteria

1. The radiation exposure criteria for all test personnel at the NTS are established for each series of tests by AEC Headquarters.

2. AEC Manual Chapter 0523 and 0524 contain the radiological safety criteria for peaceful uses.

3. External Whole Body Radiation

(a) Quarterly Dose. Shall not exceed 3 rems (gamma + neutron).

(b) Yearly Dose. Shall not exceed 5 rems (whole body gamma + neutron) except as listed below.

(c) Exceptions

(1) If the individual's MPD minus his previous lifetime cumulative dose is less than 5 rem no exposure which will cause him to exceed his MPD will be authorized.

(2) If the individual's MPD minus his previous lifetime cumulative occupational dose is greater than 5 rem an added exposure may be allowed provided the parent organization has maintained an accurate record of the individual's lifetime radiation exposure. The Test Manager is authorized to approve an increase in the exposure, and in no case will more than 12 rem per year be authorized. All work requests must be fully justified by the user as to the need and requirement to receive an authorization to exceed the 5 rem per year radiation dose.

(3) The Test Manager may approve requests from the Director, DOD Test Group for an increase in the operational radiation exposure when submitted in accordance with the special limits prescribed by the Armed Forces.

(d) Accidental Dose. Provisions of NBS Handbook 59 shall pertain in the case of an accidental or emergency exposure.

4. Radiation Concentration Guides. The maximum permissible body burdens and concentrations (MPC) in air and water of radio-nuclides are contained in National Bureau of Standards Handbook 69 (June 1959).

b. Radiation Contamination from Weapons Testing

1. Allowable vehicle and equipment contamination must not exceed:

7 mr/hr (gamma)

400 d/m/55 cm^2 (removable alpha by swipe)

1000 d/m/55 cm^2 (fixed alpha)

By "fixed" alpha is meant that no change in the alpha contamination level can be detected by swiping a one square-foot area and monitoring the swipe. These measurements are made by portable survey instruments.

2. Personnel contamination should be maintained as low as possible and decontamination exercised when levels exceed those shown:

Item	Alpha d/m/55 cm^2	Gamma mr/hr
Outer Clothing	1000	7
Shoes	1000	7
Skin or Underclothing	200	1

3. Respirator protective devices will be maintained at a contamination level less than 1 mr/hr (beta+gamma) or 200 d/m/55 cm^2 (alpha fixed or removable).

4. Equipment or vehicles, alpha contaminated to levels in excess of 10,000 d/m/55 cm^2, will be decontaminated by mobile equipment in the field prior to transporting to the decontamination pad.

c. Radiation levels from reactor testing. Maximum permissible radiation levels will be as specified in the Test Group Director's Operational Plan.

045 Film Badge Procedures

a. All personnel entering NTS must wear a current gamma-measuring film badge. These will be attached and worn with the security badge, and will be routinely exchanged each month.

b. Neutron film badges will be issued to individuals working with neutron sources, or working in the reactor areas when required by test operations. These badges will be exchanged and processed whenever an individual or group of individuals could have received a dose greater than 100 mrem or at the end of each calendar quarter, whichever is sooner.

c. Dosimeters will be worn by all personnel working in a radiation area in which it is possible to receive in a normal working day a radiation dose greater than 100 mrem.

d. Film badges will be exchanged by all personnel at the nearest Rad-Safety facility immediately after leaving a radiation area or zone in which a pocket dosimeter reading shows a dosage of 100 mr or greater, or at any time a greater exposure is suspected. These badges will be processed each work day.

e. Individuals returning to their home stations, or otherwise terminating their participation with an activity at the NTS, will turn in their film badges as a part of the Mercury checkout procedures. Film badges will be collected and processed each work day for these departing individuals and the dosage results will be reported to the appropriate agency within 24 hours from processing if the film badge processing indicates a dosage greater than 100 mrem.

046 Radiological Surveys.

When operational rad-safety control has been delegated to a Test Group Director under 012a, the Director will be responsible for the initial radiation survey of the specified area after an operation. Permission for entry into the area prior to completion of the initial survey lies solely with the Director. After the radiological situation has stabilized, he will advise all other parties of the situation, and will permit operations in the area in accordance with his published safety plan.

047 Entry into Controlled Areas

a. The Test Group Director or Area Manager, LVAO (as appropriate), is responsible for establishing a controlled area when required for reasons of radiation safety. These areas will normally be established when: (1) the radiation intensities require precautions to limit personnel exposure, (2) it is anticipated that radiation or use of radioactive material could cause a problem, (3) it is possible through an accident or otherwise that an experimental program could produce radiation, or (4) the Test Group Director or Area Manager considers it desirable for any safety reason to control entry of personnel.

b. Procedures to control access of personnel will be established by the Area Manager, LVAO, or by the Test Group Director if the provisions of subsection 012a apply. The specific details on access procedures and precautions necessary to protect personnel from the radiation hazards associated with a particular program will be contained in the Test Group Director's Operation Plan.

c. In the event of an emergency, the Test Manager, Test Group Director, or their authorized representatives may authorize entry into a precise location. This authorization may be verbal.

048 Radiation Exposure Control

a. Control of Exposure

1. Recovery parties will not enter areas with radiation intensities in excess of 10 r/hr unless specifically authorized by cognizant authority.

2. Surveys to establish isointensity lines greater than 1000 mr/hr will not be conducted as a routine function for each experiment.

3. Construction activities in radex areas will be accomplished only at the discretion of the Area Manager, LVAO.

4. Eating and smoking in radex areas or controlled area will be prohibited.

b. Monitors

1. Participating organizations will normally provide their own monitors. If they are unable to do so, the REECo Rad-Safety Organization will provide monitors.

2. The REECo Rad-Safety Organization will provide training courses for project monitors as required.

3. All participating organizations will provide a list of certified monitors to the REECo Rad-Safety Division.

c. Anti-Contamination Clothing and Equipment. Necessary rad-safety equipment, including instruments, clothing, respirators, film badges and dosimeters may be obtained at the Rad-Safety Building (CP-2) or the Reactor Test Area Rad-Safety Facility.

d. Decontamination

1. Vehicles and equipment found to be contaminated will be taken to the decontamination station adjacent to the Rad-Safety Building (CP-2) or the Reactor Test Area Rad-Safety Facility.

2. Monitoring and decontamination of aircraft will be provided by the on-site rad-safety organization when requested.

049 Radioactive Material Control

a. Definitions

1. Controlled Radioactive Sources: Any encapsulated radioactive source that has an associated dose rate greater than 1.5 rem/hr at one yard.

2. Registered Radioactive Sources:

(a) Plutonium, Polonium and Radium: those greater than 0.1 millicuries

(b) Barium ^{140}, Strontium ^{89}, Strontium ^{90}, Yttrium^{91}: those greater than 0.135 mc

(c) All other sources greater than 1.35 mc not controlled under 049 a-1 above.

b. Radioactive Source Control Procedures

1. In advance of receipt of source at NTS, the using agency is responsible for submitting to the Area Manager, LVAO, for information and comment (with a copy to the Assistant Manager for Test Operations, ALO), written operating and radiological safety procedures for controlling the use of any radioactive source as defined in a-1 above. The following information is required:

   (a) Time of arrival at NTS.

   (b) Isotope or isotopes involved.

   (c) Proposed use of the radioactive material.

   (d) Statement that shipment will comply with ICC shipping regulations or other appropriate AEC regulations.

   (e) Where the source will be stored.

   (f) Final disposition of source.

   (g) Operating procedures which will be followed in storing and working with the source.

   (h) Name of individual responsible for radiological safety.

   The Assistant Manager, OTO, will review all operational plans and procedures and will furnish the using agency with appropriate comments.

2. The senior on-site representative of user scientific laboratory, agency. or organization is responsible for notifying the REECo Rad-Safety Division in advance of the movement of any radioactive material, as defined in a-1 above, to other locations unless covered by operational procedures established in b-1 above.

3. Agencies using calibration sources will be familiar with radiological safety procedures for use of radioactive sources. The REECo Rad-Safety Division will assist user agencies in developing operational plans and procedures on request.

4. All radioactive material as defined in 049a, exclusive of source and nuclear material (SSN) brought onto the NTS, will be registered with the REECo Rad-Safety Division at the time of entry onto the test site.

5. The Area Manager, LVAO, is responsible for making periodic inspection of user agency source control procedures and reporting such inspections with appropriate recommendations to the Assistant Manager for Test Operations, ALO.

c. Radioactive Waste Material Control Procedures

1. The REECo Rad-Safety Division is responsible for disposing of radioactive waste material, on the NTS, except as defined in c-2 below. A radiological safety plan and control procedures will be submitted by REECo to the Area Manager, LVAO, for review and comment, with a copy to the Assistant Manager for Test Operations, ALO.

2. Disposal of radioactive waste material as a result of operations in the 400 and 401 areas is the responsibility of the Project Test Group Director.

d. Removal of Radioactive Material

1. All shipments of radioactive materials, except as exempted in d-2 below, will be labelled according to appropriate Interstate Commerce Commission, Civil Aeronautics Board, U. S. Coast Guard, and U. S. Postal regulations. Arrangements for packaging shipments will be the responsibility of the organization initiating the shipment. Shipping records will be initiated on an on-site Rad-Safety shipping form and will be completed and certified by the REECo Rad-Safety organization.

2. Scientific samples, instruments and equipment designated by the Test Group Director are exempt from the above procedural requirements when transported by courier vehicle or fly-away aircraft. A suitable record of exempted material will be maintained by the REECo Rad-Safety Organization.

e. Reports and Records

1. The REECo Rad-Safety Division is responsible for submitting monthly to the Area Manager, LVAO, a map showing the specific areas of radioactive contamination within NTS, showing locations, levels and types of radiation.

2. The REECo Rad-Safety Division is responsible for maintaining an up-to-date master file showing the ownership, source strength and specific location of all radioactive sources on the Nevada Test Site.

0410 Dosimetry and Records

a. The REECo Rad-Safety Organization will provide dosimetry and record services for both the on-site and off-site organizations and maintain dosimetry records on all on-site personnel. Dosage reports will be submitted for all personnel to the Area Manager, LVAO, and to the Test Group Director on a monthly basis. The Test Group Director and the Area Manager, LVAO, will also be provided with a report of all integrated exposure in excess of 2 rems (gamma + neutron) on a daily and monthly basis as outlined.

b. A quarterly exposure report will be furnished to the Area Manager, LVAO, and to the Assistant Manager, Office of Test Operations, ALO.

c. Record disposition policies and regulations shall be in accordance with the provisions of AEC Appendix 0203-091-11, Sections 5 and 6.

0411 Documenting Decontamination

At the time any area decontamination has been completed, REECo will submit a report in quadruplicate to the Test Manager, including such data as: a map of the area showing radiation intensities, radiation levels at specific locations prior to decontamination, radiation levels upon completion, effect of character of terrain on radiation intensities, type of equipment used on the job, dosages equipment operators received, effectiveness of the decontamination, time required to complete the decontamination, photographs, and any other pertinent facts relating to the problem.

0412 Counting Laboratory

A counting laboratory for determining gross radioactivity will be operated in Mercury by the On-Site Rad-Safety Organization. Analysis for specific material such as plutonium, tritium, and beryllium will be made for user organizations as a routine support service, if requested.

0524-05 Off-Site Rad-Safety Operations

051 Purpose

a. The purpose of this plan is to set forth the general procedures to be followed by the U. S. Public Health Service Off-Site Rad-Safety Organization in providing off-site radiological safety support on a continuous basis and for test activities at the Nevada Test Site.

b. Detailed monitoring and sample collection procedures are contained in the Off-Site Radiological Safety Plan.

052 Definition of Terms

The Off-Site Area is defined as the area surrounding NTS to a radius of about 250 miles.

053 Responsibilities

a. During non-test periods the Public Health Service Off-Site Rad-Safety Organization is responsible to the Area Manager, LVAO, for:

1. Analyzing data and preparing final off-site reports of previous series and special reports as requested.

2. Preparing detailed operational plans for forthcoming series.

3. Maintaining an active film badge program as required to fully document the gamma dosage to off-site populations and communities.

4. Maintaining an active public education program, including periodic visits to communities.

5. Maintaining an environmental sampling program, including air, water, and foodstuffs.

6. Maintaining liaison with State and local health officials in the off-site area.

7. Providing an off-site monitoring service.

b. During a test period the Public Health Service Off-Site Rad-Safety Organization is responsible to the Area Manager, LVAO, for:

1. Providing the same services as during the non-test period, on an expanded scale to meet increased testing activities.

2. Fully documenting the off-site radiological situation following each test activity in which radioactive fallout could be detected off-site.

3. Maintaining an up-to-date map of the off-site area showing the locations and levels of any radiation.

4. Investigating inquiries and incidents of a medical nature from the off-site populace in accordance with the procedure contained in NTSO-SOP Chapter 0701.

054 Operational Guide - Radiation Exposure

The off-site radiological safety criterion is 0.5 roentgens per year whole body gamma exposure and one-tenth of the maximum permissible concentration of radioisotopes in air and water as listed in NBS Handbook 69. These MPC's may be averaged over a period up to one year.

055 Objectives

The objectives of the off-site radiological safety activities are as follows:

a. To verify the off-site radiological situation associated with test site activities to insure public safety.

b. To have trained personnel available to take emergency measures prescribed by the Atomic Energy Commission should an unacceptable situation develop.

c. To obtain an adequate record of the radioactivity in the off-site area.

d. To maintain public confidence that all reasonable safeguards are being employed to preserve public health and property free from radiation hazards.

e. To investigate reports of incidents attributed to radioactivity which could result in claims against the Government or create unfavorable and unwarranted public opinion.

f. To accumulate data to provide a basis for a better evaluation of cumulative radiation dose to people.

056 Organization

a. By a Memorandum of Understanding between the PHS and the AEC-ALO, the PHS is responsible to staff and operate the off-site radiological safety program at NTS.

b. PHS-commissioned officers will be permanently assigned to the Las Vegas Area Office in support of this activity. The number of officers so assigned will be by mutual agreement between the Division of Radiological Health, Public Health Service, and the Office of Test Operations.

c. The Officer-in-Charge, PHS Off-Site Activities, is the Off-Site Rad-Safety Officer.

d. The permanent staff will be augmented during test periods by personnel assigned through the Division of Radiological Health, PHS.

057 Operational Plan

a. Survey Results

1. Monitoring radiation readings will be radioed to Net Control at Mercury Bldg. 155 by the monitoring teams.

2. A carbon copy of all monitoring data will be forwarded immediately after each test activity to the Office of the Test Manager.

3. The results will be posted on a large-scale wall map in Bldg. 155 as received. The intensity and time of reading will be noted at each reading location.

4. An interim off-site radiological safety report will be prepared following each test activity for submission to the Area Manager, LVAO.

b. Environmental Sampling

1. Air sampling stations will be established in the larger population centers. Results from these stations assist in delineating the fallout pattern and documenting negative values outside the fallout area.

2. Water samples will be collected periodically at representative places such as public water supplies, stock watering ponds, and ground water surface discharges and will be counted for gross radioactivity.

3. Milk samples will be collected periodically from dairy farms, processing plants, and retail outlets in the off-site area.

4. Food samples will be collected to obtain data on internal radiation hazards to the off-site population.

5. A representative number of water, milk and food samples showing above normal gross levels will be analyzed for specific significant isotopes.

c. Public Education

1. Public relations is recognized as one of the more important functions of the off-site program. Educational activities will be directed toward individuals and groups through informal discussions, distribution of pertinent literature, showing of movies, and matter-of-fact question answering.

2. The Office of Test Information, NTSO, will furnish guidance and direction as necessary in the conduct of off-site public relations.

d. Film Badge Program

1. Film badges will be strategically placed in populated places, along highways and trails in non-populated areas, and inside and outside buildings, and will be exchanged monthly.

2. The film badges will be supplied and processed after exposure by the REECo Rad-Safety Organization.

e. Liaison with Public Health Officials

Continuous liaison will be maintained with State and local health officials. For operational periods notification of testing activities will be coordinated with appropriate test officials.

f. Instrumentation

1. Monitoring instruments for detecting alpha, beta, and gamma activity will be furnished and maintained by the Support Contractor.

2. Continuous recorders will be placed in communities to present a visual record of gamma radiation levels in these localities.

g. On-Site Data Collection—Reactor Operations:

The assignment of areas of responsibility for collection of data on site for periods of reactor testing will be as mutually agreed upon by the "Committee for Environmental-Radiation Studies."

058 Medical Activities

When required by test site activities, a medical officer will be assigned by the PHS Liaison Officer Network Coordinator to the staff of the Off-Site Rad-Safety Officer. He will be responsible for maintaining liaison with local physicians, answering inquiries of a medical nature, investigating complaints and conducting public relations.

059 Veterinary Activities

a. A veterinarian will be assigned by the Veterinary Corps, U. S. Army, to the AEC Las Vegas Areas Office.

b. Programmatic direction and administration will be supplied by the Area Manager, LVAO.

c. The Veterinary Officer is responsible for maintaining liaison with the local veterinarians managing the off-site animal project, answering inquiries from ranchers, and investigating complaints. He will also collect biological specimens for radiochemical analysis and will perform special studies as directed.

0510 Communications

a. The primary method of communications will be by a low-band VHF radio net. All off-site vehicles will be equipped with a 2-way radio on this net. Automatic repeater stations will be used to provide complete coverage.

b. Telephone service will be used as a secondary method of communication.

c. The Support Contractor will maintain and operate the radio net.

0511 Counting Laboratory

A low-level radiochemical laboratory will be operated at Mercury for determining gross radioactivity and specific radiochemical tests that are desirable for environmental samples in order that the Nevada Test Site Organization will be able to better evaluate cumulative low-level radiation dose to people.

0512 Emergency Plan

The Emergency Plan for evacuation of off-site population groups is outlined in NTSO SOP Chapter 0601-04.

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